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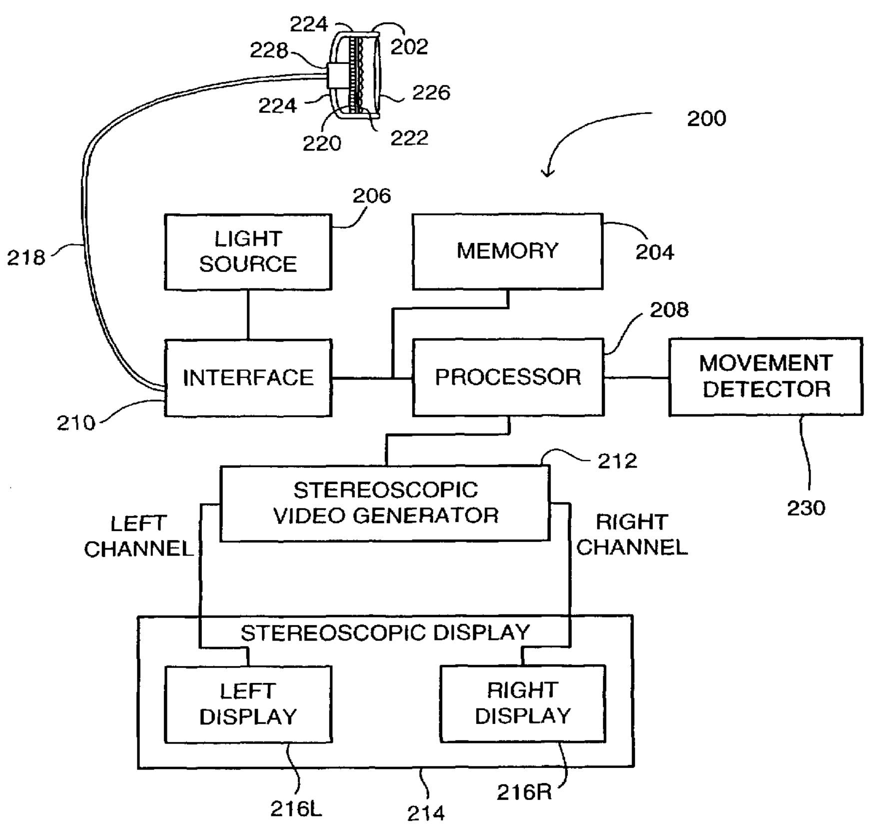
(54) Title: CAPSULE



(57) Abstract: System for producing a stereoscopic image of an object, and displaying the stereoscopic image, the system including a capsule and a control unit, the capsule including a sensor assembly (202), a processor (208) coupled with the sensor assembly, a capsule transceiver coupled with the processor, a light source (206), and a power supply for supplying electrical power to the capsule transceiver, the processor, the light source (206) and to the sensor assembly (202), the control unit including a control unit transceiver, and an image processing system connected to the control unit transceiver, wherein, the sensor assembly detects the stereoscopic image, the processor (208) captures the stereoscopic image, the capsule transceiver transmits the stereoscopic image to the control unit transceiver and the image processing system processes the stereoscopic image.

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CAPSULE

CROSS REFERENCE INFORMATION

This application is a Continuation-in-Part of application numbers 09/257,850, filed February 25, 1999 and 09/699,624, filed October 30, 2000.

FIELD OF THE DISCLOSED TECHNIQUE

The disclosed technique relates to endoscopes, microscopes and boroscopes, in general and to stereoscopic image pick up devices with color imaging capability, in particular.

BACKGROUND OF THE DISCLOSED TECHNIQUE

Stereoscopic image detection devices are known in the art. Such devices are required to obtain and provide a combination of small cross section and high image quality. It will be appreciated by those skilled in the art that high image quality, in general, is characterized by stereoscopic vision accuracy, color capabilities, high resolution and illumination requirements.

It is noted that conventional methods, which provide stereoscopic images, require a wider optical path than a monocular one. Such a widened optical path enlarges the cross-section required for the detection device considerably. Hence, the requirement for a small cross section is not maintained.

US Patent No. 5,527,263 to Zobel, et al., is directed to a dual optical path stereo endoscope with simple optical adjustment. US Patent No. 5,776,049 to Takahashi, is directed to a "Stereo Endoscope and Stereo Endoscope Imaging Apparatus" and provides a device which

utilizes a combination of two optical paths with two charge coupled devices (CCD's), capable of variable zoom.

Auto-stereoscopic devices, which utilize one optical system to provide a stereo effect, are also known in the art. Such a device is provided in US patent No. 5,603,687 to Hori, et al., which is directed to a device with two parallel optical axes and two CCD units. Hori selected an asymmetrical approach, wherein one optical channel has a large aperture for light and details, and the other optical channel provides a parallax image for stereoscopic imagery to the proximal CCD.

US Patent No. 5,613,936 to Czarnek, et al., is directed to a stereoscopic endoscope device which utilizes light polarization and time multiplexing, in order to transmit each different polarized image corresponding to left and right images multiplexed in time, through one optical channel that transfers images from the lateral side of the endoscope shaft. This endoscope has to be inserted deeper into the human cavity to receive a stereo image. It must also be used with a head mounted display device called “switched shutter glasses” that causes eye irritation. It is noted that according to Czarnek each image is received in 25% of the original quality. As much as 50% of the light received from the object, is lost due to polarization considerations and as much as 50% of the remaining information is lost due to channel switching.

US Patent No. 5,588,948, to Takahashi, et al., is directed to a stereoscopic endoscope. The stereo effect is produced by having a dividing pupil shutter, which splits the optical path onto the left and right sides, and the up and down sides. These sides are alternately projected on a proximal image pick up device, using time multiplexing. According to another aspect of this reference, a distal CCD is included, which is divided to left and right sides with a shading member separating them, for achieving space multiplexing.

US Patent No. 5,743,847 to Nakamura et al., is directed to a "Stereoscopic Endoscope Having Image Transmitting Optical-System and

Pupil Dividing Unit that are Axially Movable With Respect to Each Other", which uses a plural pupil dividing means and one optical channel. US Patent No. 5,751,341 to Chaleki, et al., is directed to a "Stereoscopic Endoscope System", which is basically a two channel endoscope, with one or two proximal image sensors. A rigid sheath with an angled distal tip could be attached to its edge and be rotated, for full view.

US Patent No. 5,800,341 to Mckenna, et al., is directed to an "Electronically Steerable Endoscope", which provides different fields of view, without having to move the endoscope, using a plurality of CCD cells and processing means. US Patent No. 5,825,534 to Strahle, is directed to a "Stereo Endoscope having a Folded Sideline Sight Line" including a stereo-endoscope optical channel, having a sight line folded relative to tube axis.

US Patent No. 5,828,487 to Greening, et al., is directed to a "Stereoscopic Viewing System Using a Two Dimensional Lens System" which in general, provides an alternative R-L switching system. This system uses a laterally moving opaque leaf, between the endoscope and the camera, thus using one imaging system. US Patent No. 5,594,497 to Ahern, et al., describes a distal color CCD, for monocular view in an elongated tube.

The above descriptions provide examples of auto-stereoscopic inventions, using different switching techniques (Time division multiplexing) and polarization of channels or pupil divisions (spatial multiplexing), all in an elongated shaft. When color image pick up devices are used within these systems, the system suffers from reduced resolution, loss of time related information or a widened cross section.

The issue of color imagery or the issue of a shaft-less endoscope is not embedded into any solution. To offer higher flexibility and to reduce mechanical and optical constraints it is desired to advance the image pick-up device to the frontal part of the endoscope. This allows much higher articulation and lends itself easily to a flexible endoscope.

Having a frontal pick up device compromises the resolution of the color device due to size constraints (at this time).

US Patent No. 5,076,687 to Adelson, is directed to an “Optical Ranging Apparatus” which is, in general a depth measuring device utilizing a lenticular lens and a cluster of pixels.

US Patent No. 5,760,827 to Faris, is directed to "Pixel Data Processing System and Method for Producing Spectrally-Multiplexed Images of Three-Dimensional Imagery for Use in Stereoscopic Viewing Thereof". This reference demonstrates the use of multiplexing in color and as such, offers a solution for having a color stereo imagery with one sensor. Nevertheless, such a system requires several sequential passes to be acquired from the object, for creating a stereo color image.

US Patent No. 5,812,187 to Watanabe, is directed to an Electronic Endoscope Apparatus. This device provides a multi-color image using a monochromatic detector and a mechanical multi-wavelength-illuminating device. The monochromatic detector detects an image, each time the multi-wavelength-illuminating device produces light at a different wavelength.

US Patent No. 5,604,531 issued to Iddan, et al., and entitled "In Vivo Video Camera System", is directed to a system for viewing the inside of the digestive system of a patient. The system includes a swallowable capsule, which views the inside of the digestive system and transmits video data, a reception system located outside the patient, and a data processing the video data. The capsule includes a light source, a window, a camera system such as a CCD camera, an optical system, a transmitter, and a power source.

The light source illuminates the inner portions of the digestive system through the window. The camera system detects the images, the optical system focuses the images onto the CCD camera, the transmitter transmits the video signal of the CCD camera, and the power source provides power to the electrical elements of the capsule. The CCD camera

can provide either black and white or color signals. The capsule can additionally include sensor elements for measuring pH, temperature and pressure.

International publication No. WO 00/22975 entitled "A Method For Delivering a Device to a Target Location", is directed to a method for viewing the inside of the digestive system, and discharging medicaments or collecting fluid or cell samples from the environment. The method employs a capsule, which includes a light source, a viewing window, a camera system, an optical system, a transmitter, a power source, and a storage compartment for releasing a medicament or collecting cell samples or fluid. The light source, viewing window, camera system, optical system, transmitter, and power source are similar to those described herein above in connection with US Patent No. 5,604,531.

One end of the capsule includes a bi-stable spring coupled between an inflexible barrier proximal to the capsule and a firm diaphragm distal to the capsule, thus forming the storage compartment. The capsule includes a pouch wall between the firm diaphragm and the capsule end. The firm diaphragm includes a piercing pin for rupturing the pouch wall. The capsule end furthermore includes a permeable area for transfer of fluid to or from the storage compartment.

The spring is extended by heating it, thus moving the firm diaphragm distally. The piercing pin ruptures the pouch wall, thereby allowing controllable amount of the medicament to exit from the storage compartment through the hole pierced in the pouch wall and through the permeable area. Conversely, the bi-stable spring is retracted in order to collect a controllable amount of fluid or cell samples, wherein the fluid transfers to the storage compartment, through the permeable area.

SUMMARY OF THE DISCLOSED TECHNIQUE

It is an object of the disclosed technique to provide a novel system for stereoscopic imaging using a lenticular lens layer and a sensor array, and a novel method for operating the same, which overcomes the disadvantages of the prior art.

In accordance with the disclosed technique, there is thus provided a system for producing a stereoscopic image of an object and displaying the stereoscopic image. The system includes a capsule and a control unit. The capsule includes a sensor assembly, a processor coupled with the sensor assembly, a capsule transceiver coupled with the processor, a light source, and a power supply. The power supply supplies electrical power to the capsule transceiver, the processor, the light source and to the sensor assembly. The control unit includes a control unit transceiver, and an image processing system coupled with the control unit transceiver. The sensor assembly detects the stereoscopic image, the processor captures the stereoscopic image, the capsule transceiver transmits the stereoscopic image to the control unit transceiver and the image processing system processes the stereoscopic image.

BRIEF DESCRIPTION OF THE DRAWINGS

The disclosed technique will be understood and appreciated more fully from the following detailed description taken in conjunction with the drawings in which:

Figure 1 is a schematic illustration of a three dimensional object and a stereoscopic vision apparatus, constructed and operative in accordance with an embodiment of the disclosed technique;

Figure 2 is a schematic illustration of a stereoscopic vision apparatus, constructed and operative in accordance with another embodiment of the disclosed technique;

Figure 3A is a schematic illustration of a super-pixel, constructed and operative in accordance with a further embodiment of the disclosed technique;

Figure 3B is a schematic illustration of the super-pixel of Figure 3A and a lenticular element, constructed and operative in accordance with another embodiment of the disclosed technique;

Figure 3C is a schematic illustration of a sensor array and a lenticular lens layer, constructed and operative in accordance with a further embodiment of the disclosed technique;

Figure 4 is a schematic illustration of a super-pixel, constructed and operative in accordance with another embodiment of the disclosed technique;

Figure 5A is a schematic illustration of a color super-pixel, constructed and operative in accordance with a further embodiment of the disclosed technique;

Figure 5B is a schematic illustration of the color super-pixel of Figure 5A, with a single lenticular element, constructed and operative in accordance with another embodiment of the disclosed technique;

Figure 5C is a schematic illustration of the color super-pixel of Figure 5A, combined with three lenticular elements, constructed and

operative in accordance with a further embodiment of the disclosed technique;

Figure 6 is a schematic illustration of a sensor array and a lenticular lens layer, constructed and operative in accordance with another embodiment of the disclosed technique;

Figure 7A is a schematic illustration of a method for operating the apparatus of Figure 2, operative in accordance with a further embodiment of the disclosed technique;

Figure 7B is an illustration in detail of a step of the method of Figure 7A;

Figure 7C is a schematic illustration of a sensor array and a lenticular lens layer, constructed and operative in accordance with another embodiment of the disclosed technique;

Figure 8 is a schematic illustration of a stereoscopic vision apparatus, constructed and operative in accordance with a further embodiment of the disclosed technique;

Figure 9A is a view in perspective of a section of light sensors, and a lenticular element, constructed and operative in accordance with another embodiment of the disclosed technique;

Figure 9B is a view from the bottom of the lenticular element and the section of light sensors of Figure 9A;

Figure 9C is a view from the side of the lenticular element and the section of light sensors of Figure 9A;

Figure 10 is a view in perspective of a section of light sensors, and a lenticular element, constructed and operative in accordance with a further embodiment of the disclosed technique;

Figure 11 is a view in perspective of a sensor array and a lenticular lens layer, constructed and operative in accordance with another embodiment of the disclosed technique;

Figure 12A is a schematic illustration of a detection apparatus, constructed and operative in accordance with a further embodiment of the disclosed technique;

Figure 12B is another schematic illustration of the detection apparatus of Figure 12A;

Figure 13 is a schematic illustration of a detection apparatus, constructed and operative in accordance with another embodiment of the disclosed technique;

Figure 14A is a partially schematic partially perspective illustration of a combined illumination and detection device, constructed and operative in accordance with a further embodiment of the disclosed technique;

Figure 14B is a partially schematic partially perspective illustration of the combined illumination and detection device of Figure 14A, a controller and output frames, constructed and operative in accordance with another embodiment of the disclosed technique;

Figure 15 is an illustration in perspective of a color illumination unit, constructed and operative in accordance with a further embodiment of the disclosed technique;

Figure 16 is a view in perspective of a sensor array and a partial lenticular lens layer, constructed and operative in accordance with another embodiment of the disclosed technique;

Figure 17 is a view in perspective of a sensor array and a partial lenticular lens layer, constructed and operative in accordance with a further embodiment of the disclosed technique;

Figure 18 is a schematic illustration of a sensor array and a partial lenticular lens layer, constructed and operative in accordance with another embodiment of the disclosed technique;

Figure 19 is a schematic illustration of a sensor array and a partial lenticular lens layer, constructed and operative in accordance with a further embodiment of the disclosed technique;

Figure 20A is a schematic illustration of a system, for producing a color stereoscopic image, in a right side detection mode, constructed and operative in accordance with another embodiment of the disclosed technique;

Figure 20B is an illustration of the system of Figure 20A, in a left-side detection mode;

Figure 21A is a schematic illustration of a timing sequence, in which the controller of the system of Figure 20A synchronizes the operation of illumination unit, apertures and image detector of that same system;

Figure 21B is a schematic illustration of another timing sequence, in which the controller of Figure 20A synchronizes the operation of the illumination unit, right and left apertures and the image detector;

Figure 22 is a schematic illustration of a method for operating the system of Figures 20A and 20B, operative in accordance with a further embodiment of the disclosed technique;

Figure 23 is a schematic illustration of a timing scheme, for operating the system of Figures 20A and 20B, in accordance with another embodiment of the disclosed technique;

Figure 24 is a schematic illustration of a timing scheme, for operating the system of Figures 20A and 20B, in accordance with a further embodiment of the disclosed technique;

Figure 25A is a schematic illustration of an object and a sensor assembly, when the sensor assembly is located at an initial position with respect to the object;

Figure 25B is a schematic illustration of the object and the sensor assembly of Figure 25A, when the sensor assembly has moved to a new position;

Figure 25C is a schematic illustration of the object and the sensor assembly of Figure 25A, when the sensor assembly has moved to another position;

Figure 25D is a schematic illustration of the object and the sensor assembly of Figure 25A, when the sensor assembly has moved to a further new position;

Figure 25E is a schematic illustration of the object and the sensor assembly of Figure 25A, when the sensor assembly has moved to another new position;

Figure 25F is a schematic illustration of the object and the sensor assembly of Figure 25A, when the sensor assembly has moved to a further new position;

Figure 26A is a schematic illustration of a detected image, as detected by sensor assembly of Figure 25A, and a respective displayed image, in accordance with a further embodiment of the disclosed technique;

Figure 26B is a schematic illustration of a detected image, as detected by sensor assembly of Figure 25B, and a respective displayed image;

Figure 26C is a schematic illustration of a detected image, as detected by the sensor assembly of Figure 25C, and a respective displayed image;

Figure 27A is a schematic illustration of a sub-matrix, in accordance with another embodiment of the disclosed technique, when the sensor assembly is at a location illustrated in Figure 25A;

Figure 27B is a schematic illustration of a sub-matrix, when the sensor assembly is at a location illustrated in Figure 25B;

Figure 27C is a schematic illustration of a sub-matrix, when the sensor assembly is at a location illustrated in Figure 25C;

Figure 27D is a schematic illustration of a sub-matrix, when the sensor assembly is at a location illustrated in Figure 25D;

Figure 27E is a schematic illustration of a sub-matrix, when the sensor assembly is at a location illustrated in Figure 25E;

Figure 27F is a schematic illustration of a sub-matrix, when the sensor assembly is at a location illustrated in Figure 25F;

Figure 28 is a schematic illustration of an imaging system, constructed and operative in accordance with a further embodiment of the disclosed technique;

Figure 29 is a schematic illustration of an imaging system, constructed and operative in accordance with another embodiment of the disclosed technique;

Figure 30 is a schematic illustration of an imaging system, constructed and operative in accordance with a further embodiment of the disclosed technique;

Figure 31 is a schematic illustration of a capsule, constructed and operative in accordance with another embodiment of the disclosed technique;

Figure 32A is a schematic illustration of a capsule, constructed and operative in accordance with a further embodiment of the disclosed technique; and

Figure 32B is an illustration of the capsule of Figure 32A, in a different detection mode.

DETAILED DESCRIPTION OF THE EMBODIMENTS

The disclosed technique overcomes the disadvantages of the prior art by providing a continuous vision stereoscopic apparatus, using a generally lenticular lens layer, a light sensor array and an image processing system.

Reference is now made to Figure 1, which is a schematic illustration of a three dimensional object and a stereoscopic vision apparatus, generally referenced 100, constructed and operative in accordance with an embodiment of the disclosed technique. Apparatus 100 includes a lenticular lens layer 104, a light sensor array 102, a processor 106 and two display devices 108R and 108L. Apparatus 100 is placed in front of a three-dimensional object 150. An optical assembly 152 is placed between apparatus 100 and object 150, for focusing the image of object 150 on light sensor array 102.

Light sensor array 102 includes a plurality of sensors 110, 111, 112, 113, 114, 115, 116, 117, 118 and 119. Lenticular lens layer 104 includes a plurality of lenticular elements 130, 132, 134, 136 and 138. Each one of the lenticular elements is located above two light sensors, in a way that lenticular element 130 is located above light sensors 110 and 111 and lenticular element 132 is located above light sensors 112 and 113. Furthermore, lenticular element 134 is located above light sensors 114 and 115, lenticular element 136 is located above light sensors 116 and 117 and lenticular element 138 is located above light sensors 118 and 119.

The light sensors 110, 111, 112, 113, 114, 115, 116, 117, 118, and 119, detect light as directed by the lenticular lens elements 130, 132, 134, 136 and 138, and provide respective information to the processor 106. The processor 106 processes this information, produces a pair of images, as will be explained in detail herein below, and provides them to the display units 108R and 108L, which in turn produce visual representations of these images.

In general, each lenticular element directs light rays, which arrive from a predetermined direction to a predetermined location, and light rays which arrive from another predetermined direction, to another predetermined location. Hence, the disclosed technique, utilizes the lenticular lens layer to distinguish between a right view image and a left view image, as is described herein below.

Each of the display units 108R and 108L includes a plurality of display units also known as pixels. Display unit 108L includes pixels 142A, 142B, 142C, 142D and 142E. Display unit 108R includes pixels 144A, 144B, 144C, 144D and 144E. Using these pixels each of the display units 108R and 108L produces an image, according to data provided from the processor 106. The two images, each viewed by a different eye of the user, produce a sensation of a three-dimensional image.

Light rays 124A, and 126A represent a right-side image of the three-dimensional object 150. Light rays 120A, and 122A represent a left side image of the three-dimensional object 150. The optical assembly 152 redirects light rays 120A, 122A, 124A and 126A so as to focus them on a plain which is determined by the light sensor array 102, as light rays 120B, 122B, 124B and 126B, respectively. Hence, light rays 122B and 126B represent a focused right side view of the three-dimensional object 150, and light rays 120B and 124B represent a focused left side view of the three-dimensional object 150.

The lenticular lens layer 104 directs the focused right side view light rays 122B and 126B to light sensors 110 and 118, respectively, as respective light rays 122C and 126C. In addition, the lenticular lens layer 104 directs the focused left side view light rays 120B and 124B to light sensors 111 and 119, respectively. In general, light sensors 111, 113, 115, 117 and 119 detect light rays which relate to a left side view image of object 150, and light sensors 110, 112, 114, 116, and 118, detect light rays which relate to a right side view image of object 150.

Hence, light sensors 110, 112, 114, 116 and 118 detect the right side image of object 150, while light sensors 111, 113, 115, 117 and 119 detect the left side image of object 150. The light sensor array 102 provides data relating to the detected light intensity at each of the light sensors to the processor 106.

The processor 106 processes this data, produces a right side image from the data relating to the right side view and a left side image from the data relating to the left side view, and provides the respective image to the respective display unit 108R and 108L. In the present example, the processor 106 utilizes the data received from sensors 110, 112, 114, 116 and 118 to determine the data provided to pixels 144A, 144B, 144C, 144D and 144E, respectively. Similarly, the processor 106 utilizes the data received from sensors 111, 113, 115, 117 and 119 to determine the data which is to be provided to pixels 142A, 142B, 142C, 142D and 142E, respectively.

According to the disclosed technique, the right side image and the left side image are detected at the same time and hence, can also be displayed at the same time. According to another aspect of the disclosed technique, each of the light sensors 110, 111, 112, 113, 114, 115, 116, 117, 118, and 119, includes a plurality of color sensing elements, which together cover a predetermined spectrum, as will be described in detail herein below.

Reference is now made to Figure 2, which is a schematic illustration of a stereoscopic vision apparatus, generally referenced 200, constructed and operative in accordance with another embodiment of the disclosed technique. Apparatus 200 includes a sensor assembly 202, an interface 210, a processor 208, a movement detector 230, a light source 206, a memory unit 204, a stereoscopic video generator 212 and a stereoscopic display 214. The sensor assembly 202 is coupled with the interface 210 by a flexible cord 218. The interface 210 is coupled with processor 208, memory unit 204, and to light source 206. The processor

208 is further coupled with the memory unit 204, movement detector 230 and to the stereoscopic video generator 212. The stereoscopic video generator 212 is further coupled with the stereoscopic display 214.

Movement detector 230 detects the movement of sensor assembly 202 relative to an object. For this purpose, movement detector 230 is attached to sensor assembly 202. In the case of a rigid endoscope, the movement detector 230 can be attached to any part of the endoscope rod (not shown), since the movement of the endoscope head can be determined according to the movement of any point of the endoscope rod. The operation of system 200, according to data received from movement detector 230, is described herein below.

The sensor assembly 202 includes a focusing element, which in the present example is a lens 226, a lenticular lens layer 222, a light sensor array 220, an interface 228 and a light projecting means 224. The lenticular lens layer 222 is attached to the light sensor array 220. According to the disclosed technique, the light sensor array 220 can be any type of sensing array, such as a CCD detector, a CMOS detector, and the like. The light sensor array 220 is coupled with the interface 228, which can also acts as a supporting base.

The stereoscopic display 214 includes two display units, a left display unit 216L (for placing in front of the left eye of the user) and a right display unit 216R (for placing in front of the right eye of the user). Hence, the stereoscopic display 214 is capable of displaying stereoscopic images continuously. Such a stereoscopic display unit is for example the ProView 50 ST head-mounted display, manufactured and sold by Kaiser Electro-Optics Inc., a US registered company, located in Carlsbad, California. Another example of a stereoscopic display unit is the virtual retinal display (VRD) unit, which is provided by MICROVISION Inc., a US registered company, located in Seattle, Washington. It is noted that any method, which is known in the art for displaying stereoscopic, and for that matter three-dimensional images, is applicable to the disclosed technique.

The image received from a three-dimensional object is received at the sensor assembly 202, focused by lens 226, optically processed by the lenticular lens layer 222 and finally detected by the light sensor array 220. The lenticular lens layer 222 directs light coming from one predetermined direction to predetermined light sensors of the light sensor array 220, and light coming from another predetermined direction to other predetermined light sensors of the light sensor array 220. Accordingly, light sensor array 220 detects two images of the same object, a right side image and a left side image, each from a different direction. This aspect of the disclosed technique is described in detail hereinabove, in conjunction with Figure 1.

An electronic representation of this information is partially processed by the interface 228 and then provided to the interface 210, via flexible cord 218. It is noted that flexible cord 218 includes digital communication linking means such as optic fibers or electrical wires, for transferring data received from light sensor array 220, as well as light guiding conducting means for conducting light from light source 206 to the light projecting means 224. According to the disclosed technique, flexible cord 218 can be replaced by a rigid cord (not shown), if necessary.

The data received at interface 210 includes information, which relates to the two images and has to be processed so as to distinguish them from each other. As the processor 208 processes the information, it uses the memory unit 204 as temporarily storage.

After processing the information, the processor 208 produces two matrices each being a reconstructed representation relating to one of the originally detected images. The processor provides these matrices to the stereoscopic video generator 212, which in turn produces two respective video signals, one for the left view image and another for the right view image. The stereoscopic video generator 212 provides the video signals to the stereoscopic display 214, which in turn produces two

images, one using right display unit 216R and another using left display unit 216L.

It is noted that the general size of the sensor assembly 202 is dictated by the size of the sensor array and can be in the order of a few millimeters or a few centimeters. This depends on the size of each of the sensors in the array and the total number of sensors (i.e. the required optical resolution).

According to one aspect of the disclosed technique, each of the sensors in light sensor array 220, is a full range sensor, which yields data relating to a gray scale stereoscopic image. According to another aspect of the disclosed technique, each of the sensors in the light sensor array, can be adapted so as to provide full color detection capabilities.

Reference is now made to Figure 3A, which is a schematic illustration of a super-pixel, generally referenced 300, constructed and operative in accordance with a further embodiment of the disclosed technique. Super-pixel 300 includes a left section of sensors which includes three sensors 302, 304 and 306, and a right section of sensors which also includes three sensors 308, 310 and 312. Sensors 302 and 310 detect generally red colored light, sensors 304 and 312 detect generally green colored light and sensors 306 and 308 detect generally blue colored light. Hence, each of the sections includes a complete set of sensors for detecting light in the entire visible spectrum.

Reference is further made to Figure 3B, which is a schematic illustration of the super-pixel 300 of Figure 3A and a lenticular element, generally referenced 318, constructed and operative in accordance with another embodiment of the disclosed technique. The lenticular element 318 is located on top of super-pixel 300, where its right side covers the right section of the super-pixel 300, and its left side covers the left section of the super-pixel 300. Accordingly, the lenticular element 318 directs light, which arrives from the right (right view image), to the left section of the

super-pixel 300, where it is detected in full spectrum by sensors 302, 304 and 306.

The data provided by these sensors can later be utilized to reconstruct an image in full color. Similarly, the lenticular element 318 directs light, which arrives from the left (left view image), to the right section of the super-pixel 300, where it is detected in full spectrum by sensors 308, 310 and 312.

Reference is now made to Figure 3C, which is a schematic illustration of a sensor array, generally referenced 330, and a lenticular lens layer, generally referenced 332, constructed and operative in accordance with a further embodiment of the disclosed technique. Sensor array 330 is a matrix of M×N super-pixels, which are generally referenced 340. For example, the upper left super-pixel is denoted $340_{(1,1)}$, the last super-pixel in the same column is denoted $340_{(1,N)}$ and the lower-right pixel is denoted $340_{(M,N)}$. A lenticular lens layer 332 of which three lenticular elements are shown (referenced 334), is placed over the sensor array 330.

Lenticular element $334_{(1)}$ covers the first column of super-pixels 340 from super-pixel $340_{(1,1)}$ to super-pixel $340_{(1,N)}$. Lenticular element $334_{(2)}$ covers the second column of super-pixels 340 from super-pixel $340_{(2,1)}$ to super-pixel $340_{(2,N)}$. Lenticular element $334_{(3)}$ covers the third column of super-pixels 340 from super-pixel $340_{(3,1)}$ to super-pixel $340_{(3,N)}$. Accordingly, each of the lenticular elements of the lenticular lens layer covers an entire column of super-pixels.

It is noted that a super-pixel according to the disclosed technique can include sensors in any set of colors such as red-green-blue (RGB), cyan-yellow-magenta-green (CYMG), infra-red, ultra-violet, and the like, in any arrangement or scheme such as columns, diagonals, and the like. It is noted that such a set of colors can be achieved either by using specific color sensitive detectors or by using color filters over the wide spectrum detectors.

Reference is further made to Figure 4, which is a schematic illustration of a super-pixel, generally referenced 350, constructed and operative in accordance with another embodiment of the disclosed technique. Super-pixel 350 includes a left section of sensors which includes four sensors 352, 354, 356 and 358 and a right section of sensors which also includes four sensors 360, 362, 364 and 366. Sensors 352 and 366 detect generally cyan colored light, sensors 354 and 360 detect generally yellow colored light, sensors 356 and 362 detect generally magenta colored light and sensors 358 and 364 detect generally green colored light. Hence, each of the sections includes a complete set of sensors for detecting light in the entire visible spectrum.

Reference is further made to Figures 5A, 5B and 5C. Figure 5A is a schematic illustration of a super-pixel, generally referenced 370, constructed and operative in accordance with a further embodiment of the disclosed technique. Figure 5B is a schematic illustration of super-pixel 370 combined with a single lenticular element, generally referenced 384, constructed and operative in accordance with another embodiment of the disclosed technique. Figure 5C is a schematic illustration of super-pixel 370 combined with three lenticular elements, generally referenced 386, constructed and operative in accordance with a further embodiment of the disclosed technique.

The color arrangement which is provided for super-pixel 370 is typical for vertical light detection arrays, where each column of sensors is coated with light filtering layer of a different color. As can be seen in Figure 5A, super-pixel 370 includes a plurality of light sensors 372, 374, 376, 378, 380 and 382. Light sensors 372 and 378 are blue color range sensors. Light sensors 374 and 380 are green color range sensors. Light sensors 376 and 382 are red color range sensors.

Reference is now made to Figure 6, which is a schematic illustration of a sensor, generally referenced 390, and a lenticular lens layer, generally referenced 392, constructed and operative in accordance

with another embodiment of the disclosed technique. Sensor 390 is logically divided into a plurality of super-pixels, generally referenced $394_{(x,y)}$. For example, the upper-left super-pixel is referenced $394_{(1,1)}$ and the lower-right side super-pixel is referenced $394_{(M,N)}$.

As can be seen from Figure 6, the color arrangement of sensor 390 is diagonal. Hence, each super pixel has a different color arrangement, and generally speaking, there are several types of super-pixels, such as red-blue (super pixel $394_{(M-2,N)}$), green-red (super pixel $394_{(M-1,N)}$) and blue-green (super pixel $394_{(M,N)}$).

Reference is now made to Figure 7A, which is a schematic illustration of a method for operating apparatus 200, operative in accordance with a further embodiment of the disclosed technique. In step 400, the apparatus 200 splits light which arrives from different directions, utilizing the lenticular lens 222. Each of the lenticular elements produces two light sectors, one sector which includes light rays arriving from the left side, and another sector which includes light rays arriving from the right side.

In step 402, the apparatus detects each light sector separately, using a plurality of light detectors, each detecting a portion of its respective sector. With reference to Figure 3B, sensors 302, 304 and 306 detect light which arrives from the lenticular element 318, at the left side sector and sensors 308, 310 and 312 detect light which arrives from the lenticular element 318, at the right side sector. Each of the sensors detects light at a sub-sector.

In step 404, the apparatus 200 determines the light characteristics as detected by each of the light sensors, at each of the sub-sectors. In step 408, the apparatus 200 utilizes the data, which was accumulated from selected sub-sectors to determine and produce an image representing a view from one side. In step 406, the apparatus 200 utilizes the data, which was accumulated from other selected sub-sectors to determine and produce an image representing a view from another side.

In step 410, the apparatus 200 displays both images using a continuous stereoscopic display device.

According to a further aspect of the disclosed technique, information from selected pixels can be used to enhance information for other pixels. For example, color information of pixels, which are associated with a first color, is used for extrapolating that color at the location of another pixel, associated with a second color.

Reference is further made to Figures 7B and 7C. Figure 7B is an illustration in detail of step 406 of Figure 7A. Figure 7C is a schematic illustration of a sensor array, generally referenced 450, and a lenticular lens layer, generally referenced 452, constructed and operative in accordance with another embodiment of the disclosed technique. Sensor array 450 includes a plurality of pixel sensors, referenced 454, each associated with a selected color. For example, pixel sensors $R_{(1,1)}$, $R_{(2,2)}$, $R_{(3,3)}$, $R_{(4,4)}$, $R_{(1,4)}$ and $R_{(4,1)}$ are associated with the red color. Pixel sensors $G_{(2,1)}$, $G_{(3,2)}$, $G_{(4,3)}$, $G_{(1,3)}$ and $G_{(2,4)}$ are associated with the green color. Pixel sensors $B_{(1,2)}$, $B_{(2,3)}$, $B_{(3,4)}$, $B_{(3,1)}$ and $B_{(4,2)}$ are associated with the blue color.

In step 420, the system, according to the disclosed technique, selects a pixel sensor, associated with a first color. With reference to Figure 7C, the selected pixel sensor according to the present example is pixel sensor $R_{(3,3)}$.

In step 422, the system determines pixels, associated with a second color, in the vicinity of the selected pixel. It is noted that these pixels can also be restricted to ones, which relate to the same image side of the selected pixel. With reference to Figure 7C, the second color is green and the green pixel sensors, in the vicinity of pixel sensor $R_{(3,3)}$, respective of the same image side are pixel sensors $G_{(5,1)}$, $G_{(3,2)}$, $G_{(3,5)}$, $G_{(5,4)}$, and $G_{(1,3)}$.

In step 424, the system calculates an approximation of the level of the green color at the location of the selected pixel $R_{(3,3)}$. It is noted that

the calculation can include a plurality of approximation procedures, such as calculating the weighted average level, depending on the location of pixel sensors $G_{(5,1)}$, $G_{(3,2)}$, $G_{(3,5)}$, $G_{(5,4)}$, and $G_{(1,3)}$, with respect to the location of the selected pixel sensor $R_{(3,3)}$. Similarly, blue color level at the location of the selected pixel sensor $R_{(3,3)}$, can be calculated using the information received from pixel sensors $B_{(1,2)}$, $B_{(1,5)}$, $B_{(3,1)}$, $B_{(3,4)}$ and $B_{(5,3)}$. Hence the disclosed technique provides a method for enhancing picture resolution by means of color information interpolation, using image processing.

It is noted that none of the lenticular elements is necessarily round shaped, but can be formed according to other optical structures which are based on various prism designs, and the like, which provide the directing of beams of light coming from different directions to different directions.

Reference is now made to Figure 8, which is a schematic illustration of a stereoscopic vision apparatus, generally referenced 500, constructed and operative in accordance with a further embodiment of the disclosed technique. Apparatus 500 includes a sensor assembly 502, a frame grabber 510, a processor 508, a light source 506, a memory unit 504, a stereoscopic video generator 512 and a stereoscopic display 514. The sensor assembly 502 is coupled with the frame grabber 510 by a flexible cord 518. The frame grabber 510, the processor 508, the memory unit 504 and the stereoscopic video generator 512 are all coupled together via a common bus.

The sensor assembly 502 is generally similar to the sensor assembly 202, as described herein above in conjunction with Figure 2. The sensor assembly 502 includes a lens 526, a lenticular lens layer 522, a light sensor array 520, an analog to digital converter (A/D) 528 and a light projecting means 524. The lenticular lens layer 522 is attached to the light sensor array 520. Light sensor array 520 is coupled with the A/D 528,

which could also act as a supporting base. The light projecting means 524 is coupled with light source 506, which provides light thereto.

The stereoscopic display 514 includes two display units, a left display unit 516L (for placing in front of the left eye of the user), and a right display unit 516R (for placing in front of the right eye of the user). Hence, the stereoscopic display 514 is capable of displaying stereoscopic images continuously. A/D converter 528 converts analog information received from light sensor array 522 into digital format and provides the digital information to frame grabber 510.

The digital information is received by the frame grabber 510 and hence made available to the processor 508 via the bus. As the processor 508 processes the information, it uses the memory unit 504 as temporary storage. After processing the information, the processor 508 produces two matrices each being a reconstructed representation relating to one of the originally detected images. The processor 508 provides these matrices to the stereoscopic video generator 512, which in turn produces two respective video signals, one for the left view image and another for the right view image. The stereoscopic video generator 512 provides the video signals to the stereoscopic display 514, which in turn produces two images, one using right display unit 516R and another using left display unit 516L.

Reference is now made to Figures 9A, 9B and 9C. Figure 9A is a view in perspective of a super-pixel, generally referenced 550, and a lenticular element, generally referenced 552, constructed and operative in accordance with another embodiment of the disclosed technique. Figure 9B is a view from the bottom of the lenticular element 552 and the super-pixel 550 of Figure 9A. Figure 9C is a view from the side of the lenticular element 552 and the super-pixel 550 of Figure 9A.

The super-pixel 550 includes four sensor sections, 554, 556, 558 and 560, arranged in a rectangular formation. The lenticular element

552 is shaped like a dome and is basically divided into four sections, each facing a different one of the sensor sections 554, 556, 558 and 560.

The super-pixel 550 and the lenticular element 552 form together, an optical detection unit, which is capable of detecting and distinguishing light which arrives from four different directions. The lenticular element 552 directs a portion of the upper-left side view of the detected object to sensor section 554 and directs a portion of the lower-left side view of the detected object to sensor section 556. In addition, the lenticular element 552 directs a portion of the upper-right side view of the detected object to sensor section 560 and a portion of the lower-right side view of the detected object to sensor section 558.

It is noted that according to a further aspect of the disclosed technique, the four-direction arrangement, which is described in Figures 9A, 9B and 9C can be used to logically rotate the image which is provided to the user, without physically rotating the device itself. At first, sensor sections 560 and 558 are used to form the right-side image and sensor sections 554 and 556 are used to form the left-side image. A rotation at an angle of 90° clockwise, is provided by assigning sensor sections 554 and 560, to form the right side image, and assigning sensor sections 556 and 558, to form the left-side image. It is further noted that a rotation in any desired angle can also be performed by means of a linear or other combination of sensor sections, when reconstructing the final images.

Reference is now made to Figure 10, which is a view in perspective of a section of light sensors, generally referenced 570, and a lenticular element, generally referenced 574, constructed and operative in accordance with a further embodiment of the disclosed technique. Lenticular element 574 is extended to cover the entire area of the section of pixels 572A, 572B, 572C and 572D, so as to enhance light transmission thereto.

Reference is now made to Figure 11, which is a view in perspective of a sensor array, generally referenced 580, and a lenticular

lens layer, generally referenced 582, constructed and operative in accordance with another embodiment of the disclosed technique. The lenticular lens layer 582 includes a plurality of four direction lenticular elements such as described in Figures 9A and 10. The sensor array 580 is logically divided into a plurality of sensor sections, generally referenced $584_{(x,y)}$. For example, the upper left sensor section is referenced $584_{(1,1)}$ and the lower-right sensor section is referenced $584_{(M,N)}$. Each of the sensor sections is located beneath a lenticular element and detects light directed thereby.

Reference is now made to Figures 12A and 12B. Figure 12A is a schematic illustration of a detection apparatus, generally referenced 600, constructed and operative in accordance with a further embodiment of the disclosed technique. Figure 12B is another schematic illustration of detection apparatus 600, of Figure 12A.

Detection apparatus 600 includes an optical assembly 602, a lenticular lens layer 604 and an array of sensors 608. The detection apparatus 600 detects images of an object 610, which includes a plurality of object sections 610A, 610B, 610C and 610D.

Sensor array 608 includes a plurality of super-pixels 608A, 608B, 608C and 608D. Each of these super-pixels is divided into a left-side section and a right-side section. For example, super-pixel 608A includes a left-side section, designated $608A_L$ and a right-side section, designated $608A_R$.

The optical assembly 602 is divided into two optical sections 602_L and 602_R, each directed at transferring an image, which represents a different side view. Optical section 602_R transfers an image, which is a view from the right side of object 610. Optical section 602_L transfers an image, which is a view from the left side of object 610.

A plurality of light rays 612, 614, 616 and 618 are directed from all sections of the object 610 to the left side of optical assembly 602 (i.e., optical section 602_L), and are directed to the lenticular lens layer 604.

Here, these rays are further directed to the left-side view associated sensor sections, which are sensor sections 608_L (i.e., sensor sections $608A_L$, $608B_L$, $608C_L$ and $608D_L$).

With reference to Figure 12B, a plurality of light rays 622, 624, 626 and 628 are directed from all sections of the object 610 to the right side of optical assembly 602 (i.e., optical section 602_R), and are directed to the lenticular lens layer 604. Here, these rays are further directed to the right-side view associated sensor sections, which are sensor sections $608A_R$, $608B_R$, $608C_R$ and $608D_R$.

Reference is now made to Figure 13, which is a schematic illustration of a detection apparatus, generally referenced 630, constructed and operative in accordance with another embodiment of the disclosed technique. Detection apparatus 630 includes an optical assembly, which is divided into four optical sections 632, 634, 636 and 638, a lenticular lens layer 642 and an array of sensors 640. The detection apparatus 630 detects images of an object 648, which includes a plurality of object sections 648A, 648B, 648C, 648D, 648E and 648F. Light rays, which arrive from object 648 to any of the optical sections 632, 634, 636 and 638, are directed to a lenticular element of the lenticular lens layer 642, according to their origin.

In the present example, all of the light rays 646A, 646B, 646C and 646D arrive from object element 648A. Each of these rays is received at a different optical section. Ray 646A is received and directed by optical section 636, ray 646B is received and directed by optical section 638, ray 646C is received and directed by optical section 634 and ray 646D is received and directed by optical section 632. Each of the optical sections directs its respective ray to a specific lenticular element $642_{(1,1)}$, at the right side of the lenticular lens layer 642. The location of lenticular element $642_{(1,1)}$ is respective of the location of the object element 648A. The lenticular element $642_{(1,1)}$ directs each of the rays to predetermined light sensors within its respective super-pixel $640_{(1,1)}$.

In accordance with a further aspect of the disclosed technique, there is provided a reduced size color stereovision detection system, which uses time-multiplexed colored light projections, and respective time-multiplexed frame grabbing.

Reference is now made to Figures 14A and 14B. Figure 14A is a partially schematic, partially perspective illustration of a combined illumination and detection device, generally referenced 650, constructed and operative in accordance with a further embodiment of the disclosed technique. Figure 14B is a partially schematic, partially perspective illustration of the combined illumination and detection device 650 of Figure 14A, a controller, generally designated 662, and output frames, constructed and operative in accordance with another embodiment of the disclosed technique.

Device 650 includes a lenticular lens layer 652, a full spectrum sensor array 654, an optical assembly 660 and an illuminating unit 656, surrounding the optical assembly 660. Illuminating unit 656 includes a plurality of illuminating elements, generally referenced 658, each being of a specific predetermined color. Illuminating elements 658_{RED} produce generally red light, illuminating elements 658_{GREEN} produce generally green light and illuminating elements 658_{BLUE} produce generally blue light. It is noted that each of the illuminating elements can be of a specific color (i.e., a specific wavelength), a range of colors (i.e., a range of wavelengths) or alternating colors, for example, a multi-color light emitting diode (LED).

Each group of illuminating elements, which are of the same color, is activated at a different point in time. For example, illuminating elements 658_{RED} are activated and shut down first, illuminating elements 658_{GREEN} are activated and shut down second and illuminating elements 658_{BLUE} are activated and shut down last. Then the illuminating sequence is repeated.

With reference to Figure 14B, the controller 662 is coupled with the sensor array 654 and with the illuminating unit 656. The sensor array 654 includes full spectrum sensors, which are capable of detecting red, green and blue light, but cannot indicate the wavelength of the detected light. The controller 662 associates the images, which are detected at any particular moment, using the sensor array 654, with the color of the illuminating elements, which were active at that particular moment.

Hence, the first detected frame 664 in an illumination sequence is considered red, since the illuminating elements which were active at that time, were illuminating elements 658_{RED}. Similarly, the second detected frame 666 in an illumination sequence is considered green, since the illuminating elements, which were active at that time, were illuminating elements 658_{GREEN}. Finally, the last detected frame 668 in an illumination sequence is considered blue, since the illuminating elements, which were active at that time, were illuminating elements 658_{BLUE}. It is noted that any other combination of colors is applicable for this and any other aspect of the disclosed technique, such as CYMG, and the like.

Reference is now made to Figure 15, which is an illustration in perspective of a color illumination unit, generally referenced 670, constructed and operative in accordance with a further embodiment of the disclosed technique. Unit 670 includes a light-guiding element 671, which is generally shaped as an open-cut hollow cone, having a narrow section 674 and a wide section 672. A detection head according to the disclosed technique, such as described in Figure 2 (referenced 202), can be placed within the hollow space of the light-guiding element 671. A multi-color light source 680 can be coupled with the narrow section 674. Light, such as light ray 678, which is emitted from the light source 680, is directed via the light guiding element 671, and is projected through the wide section 672.

According to a further aspect of the disclosed technique, a remote multi-color light source 682 can be coupled with the narrow section 674 via additional light guiding members such as optic-fibers 684. Light,

such as light ray 676, which is emitted from the light source 682, is directed via the light guiding members 684 to the narrow section 674. The light-guiding element 671 guides light ray 676, and projects it through the wide section 672. This arrangement is useful when using an external light source, which is to be placed outside the inspected area (for example, outside the body of the patient).

According to a further aspect of the disclosed technique, a full spectrum illumination unit, which produces white light, is combined with a device such as sensor assembly 202 (Figure 2).

Reference is now made to Figure 16, which is a view in perspective of a sensor array, generally referenced 700, and a partial lenticular lens layer, generally referenced 702, constructed and operative in accordance with another embodiment of the disclosed technique. The partial lenticular lens layer 702 includes a plurality of four direction lenticular elements 704 such as described in Figures 9A and 10. The sensor array 700 is logically divided into a plurality of sensor sections, generally referenced $704_{(x,y)}$. For example, the upper left sensor section is referenced $704_{(1,1)}$ and the lower-right sensor section is referenced $704_{(M,N)}$. Some of the sensor sections, in the perimeter, are located beneath lenticular elements and others, such as the sensor sections in the center rectangle, which is defined by sensor sections $704_{(4,3)}$- $704_{(7,6)}$ are not. Accordingly, the sensors which are located at the center rectangle can not be used to provide multi-direction (stereoscopic or quadroscopic) information. Instead, these sensors provide enhanced resolution monoscopic information.

Reference is now made to Figure 17, which is a view in perspective of a sensor array, generally referenced 720, and a partial lenticular lens layer, generally referenced 722, constructed and operative in accordance with a further embodiment of the disclosed technique. The partial lenticular lens layer 722 includes a plurality of four direction lenticular elements such as described in Figures 9A and 10. The sensor

array 720 is logically divided into a plurality of sensor sections, generally referenced $724_{(x,y)}$. For example, the upper left sensor section is referenced $724_{(1,1)}$ and the lower-right sensor section is referenced $724_{(M,N)}$. Here, some of the sensor sections, in the center, (such as sensor section $724_{(4,2)}$) are located beneath lenticular elements and others, such as the sensor sections in the perimeter (such as sensor section $724_{(1,1)}$) are not. Accordingly, the sensors which are located at the center provide multi-direction (stereoscopic or quadroscopic) information and the ones in the perimeter provide enhanced resolution monoscopic information.

In accordance with a further aspect of the disclosed technique there is provided a partial lenticular lens layer, which includes spaced apart lenticular elements. Reference is now made to Figure 18, which is a schematic illustration of a sensor array, generally referenced 740, and a partial lenticular lens layer, generally referenced 742, constructed and operative in accordance with another embodiment of the disclosed technique.

The partial lenticular lens layer 742 includes a plurality of lenticular elements designated $744_{(1)}$, $744_{(2)}$ and $744_{(3)}$. Lenticular element $744_{(1)}$ is located over the first two left columns of color sensors, generally referenced $746_{(1)}$, of sensor array 740. Hence, the information received from these first two left columns of color sensors of sensor array 740 contains stereoscopic information. The third and fourth columns of color sensors, generally designated $746_{(2)}$, of sensor array 740 do not have a lenticular element located thereon, and hence, cannot be used to provide stereoscopic information.

Similarly, lenticular elements $744_{(2)}$ and $744_{(3)}$ are located over color sensor column pairs, $746_{(3)}$ and $746_{(5)}$, respectively, while color sensor column pairs, $746_{(4)}$ and $746_{(6)}$ are not covered with lenticular elements.

Reference is now made to Figure 19, which is a schematic illustration of a sensor array, generally referenced 760, and a partial

lenticular lens layer, generally referenced 762, constructed and operative in accordance with another embodiment of the disclosed technique. Lenticular lens layer 762 includes a plurality of lenticular elements, referenced $764_{(1)}$, $764_{(2)}$, $764_{(3)}$ and $764_{(4)}$, being of different sizes and located at random locations over the sensor array 760. It is noted that any structure of partial lenticular lens layer is applicable for the disclosed technique, whereas the associated image processing application has to be configured according to the coverage of that specific lenticular lens layer, and to address covered sensors and uncovered sensors appropriately.

In accordance with a further aspect of the disclosed technique, there is provided a system, which produces a color stereoscopic image. The structure of the stereoscopic device defines at least two viewing angles, through which the detector can detect an image of an object. According to one aspect of the disclosed technique, the stereoscopic device includes an aperture for each viewing angle. Each of the apertures can be opened or shut. The stereoscopic device captures a stereoscopic image, by alternately detecting an image of an object, from each of the viewing angles, (e.g., by opening a different aperture at a time and shutting the rest) through a plurality of apertures, (at least two), each time from a different aperture. The final stereoscopic image can be reconstructed from the images captured with respect to the different viewing angles.

The detection of stereoscopic color image is provided by illuminating the object with a sequence of light beams, each at a different wavelength, and detecting a separate image for each wavelength and aperture combination.

Reference is now made to Figures 20A and 20B. Figure 20A is a schematic illustration of a system, generally referenced 800, for producing a color stereoscopic image, in a right side detection mode, constructed and operative in accordance with a further embodiment of the disclosed

technique. Figure 20B is an illustration of the system of Figure 20A, in a left-side detection mode.

System 800 includes a multiple aperture 804, a controller 834, an image detector 812, a storage unit 836, an image processor 838, a movement detector 814 and an illumination unit 830. Image detector 812 includes a plurality of detection elements 808A, 808B, 808C and 808D. The controller 834 is coupled with the multiple aperture 804, the image detector 812, the storage unit 836, movement detector 814 and to the illumination unit 830. The storage unit 836 is further coupled with the image processor 838. The multiple aperture 804 includes a plurality of apertures, generally referenced 802_i, where each aperture can be activated to be open or closed. It is noted that when an aperture is open it is at least transparent to a predetermined degree to light, and when an aperture is closed, it substantially prevents the travel of light there through. Any type of controllable light valve can be used to construct each of the apertures. Movement detector 814 detects the movement of image detector 812. The detected movement can be a linear displacement, an angular displacement, and the derivatives thereof such as velocity, acceleration, and the like. The operation of system 800, according to data received from movement detector 814, is described herein below in connection with Figures 25A, 25B, 25C, 26A, 26B and 26C.

Light valve elements are components, which have an ability to influence light in at least one way. Some of these ways are, for example: scattering, converging, diverging, absorbing, imposing a polarization pattern, influencing a polarization pattern which, for example, may be by rotation of a polarization plane, and the like. Other ways to influence light can be by influencing wavelength, diverting the direction of a beam, for example by using digital micro-mirror display (also known as DMD) or by using field effect, influencing phase, interference techniques, which either block or transfer a portion of a beam of light, and the like. Activation of light valve elements, which are utilized by the disclosed technique, can be

performed either electrically, magnetically or optically. Commonly used light valve elements are liquid crystal based elements, which either rotate or create and enforce a predetermined polarization axis.

In the present example, multiple aperture 804 includes two apertures 802_R and 802_L. The controller 834 further activates the multiple aperture 804, so as to alternately open apertures 802_R and 802_L. In Figure 20A, aperture 802_R is open while aperture 802_L is closed and in Figure 20B, aperture 802_R is closed while aperture 802_L is open.

Light rays, which reflect from various sections of an object 810, pass through the currently open aperture (802_R in Figure 20A and 802_L in Figure 20B). Thereby, light rays 822 and 824 arrive from a section 810A of object 810, pass through aperture 802_R, and are detected by detection element 808A, while light rays 826 and 828 arrive from a section 810D of object 810, pass through aperture 802_R and are detected by detection element 808D. Hence, when aperture 802_R is open, the system 800 provides a right side view of the object 810.

With reference to Figure 20B, when aperture 802_L is open, light rays 827 and 825 arrive from section 810A, pass through aperture 802_L, and are detected by detection element 808A, while light rays 821 and 823 arrive from section 810D, pass through aperture 802_L, and are detected by detection element 808D. Thereby, the system 800 provides a left side view of the object 810.

The illumination unit 830 is a multi-color illumination unit, which can produce light at a plurality of wavelengths. The controller 834 provides a sequence of illumination commands to the illumination unit 830, so as to produce a beam at a different predetermined wavelength, at each given moment. In the present example, the illumination unit is a red-green-blue (RGB) unit, which can produce a red light beam, a green light beam and a blue light beam. It is noted that illumination unit 830 can be replaced with any other multi-color illumination unit, which can produce either visible

light, non-visible light or both, at any desired wavelength combination (CYMG, and the like).

Furthermore, illumination unit 830 can be a passive unit, where it receives external commands to move from one wavelength to another, or it can be an active unit, which changes wavelength independently and provides an indication of the currently active wavelength to an external controller. Illumination unit 830 of the present example is a passive unit, which enhances the versatility of the system 800, by providing any wavelength sequence on demand.

In accordance with one aspect of the disclosed technique, image detector 812 is a full range color detector, where each of the detection elements is operative to detect light in a plurality of wavelengths. In accordance with another aspect of the disclosed technique, the image detector 812 is a color segmented detector, where the detection elements are divided into groups, each operative to detect light in a different range of wavelengths. One conventional type of such detectors includes a full range detection array, which is covered by a color filter layer, where each detection element is covered by a different color filter. Accordingly, some of the detection elements are covered with red filters, others are covered with green filters and the rest are covered with blue filters.

The disclosed technique enhances the color resolution of systems, using such color detectors. It will be appreciated by those skilled in the art that a color segment detector of poor quality may exhibit a wavelength (color) overlap between the different detection elements. For example, when the filters are of poor quality, their filtering functions tend to overlap such that the red filter also passes a small amount of either green or blue light. Hence, the detection element behind the red filter, also detects that small amount of green or blue light, but provides an output measurement as a measurement of red light. Hence, the color detector produces an image, which includes incorrect measurements of red light (e.g. more than the actual red light, which arrived at the detector) as result

of that overlap. Accordingly, received information of the inspected object is not valid.

In the disclosed technique, the illumination unit 830 produces a sequence of non-overlapping illumination beams at predetermined wavelengths (i.e., red, blue and green). As explained above, the color segment detector detects an image, which includes incorrect measurements, as a result of the wavelength (color) filtering overlap. Since the illumination unit 830 and the image acquisition process are synchronized, the imaging system can process each of the acquired images, according to the actual light beam color, which was produced therewith. For example, the illumination unit 830 produces blue light illumination beam. At the same time the image detector 812 detects an image, which also includes actual light measurements in detection elements, which are covered with green and red filters, due to the wavelength overlap. The imaging system can discard light measurements, which are received from detection elements, covered with color filters, which are not blue (e.g., red and green).

Such sequenced color illumination of the object, provides enhanced color resolution, for color image detectors of poor quality, and obtains the valid color images of the inspected object. System 800 can further include a stereoscopic display unit (not shown), coupled with controller 834 for displaying a stereoscopic image of object 810.

Reference is further made to Figure 21A, which is a schematic illustration of a timing sequence, in which controller 834 (Figure 20A) synchronizes the operation of illumination unit 830, apertures 802_L and 802_R, and image detector 812. Signal 840 represents the timing sequence of the left aperture 802_L. Signal 842 represents the timing sequence of the right aperture 802_R. Signal 844 represents the timing sequence of the blue light beam, produced by the illumination unit 830. Signal 846 represents the timing sequence of the green light beam, produced by the illumination unit 830. Signal 848 represents the timing sequence of the red light beam,

produced by the illumination unit 830. Signal 841 represents the timing sequence of the image detector 812, where each image is downloaded therefrom.

Timing sequence 841 rises every time any of the rises of sequences 844, 846 and 848 intersect with a rise of either sequence 842 or sequence 840. For example, rise 841_A indicates a frame download of a blue light – right aperture combination, rise 841_B indicates a frame download of a green light – right aperture combination, and rise 841_C indicates a frame download of a red light – right aperture combination. Similarly, rise 841_D indicates a frame download of a blue light – left aperture combination, rise 841_E indicates a frame download of a green light – left aperture combination and rise 841_F indicates a frame download of a red light – left aperture combination.

It is noted that for some light sources, the produced light beams do not cover the full range of visible light. For such light sources, the missing color components can be reconstructed (interpolated) by taking into consideration the physiological assumption, that color reflection response as a function of reflected angle, does not change much with angle.

Reference is further made to Figure 22, which is a schematic illustration of a method for operating system 800 of Figure 20A and 20B, operative in accordance with another embodiment of the disclosed technique. In step 870, a sequence of illumination beams at predetermined wavelengths is produced. With reference to Figures 20A and 20B, controller 834 provides a sequence of illumination commands to the illumination unit 830, which in turn produces different wavelength light beams, generally referenced 832, at predetermined points in time, toward object 810.

In step 872 right and left apertures are alternated. Light rays, which reflect from various sections of the object 810, pass through the currently open aperture (802_R in Figure 20A and 802_L in Figure 20B). With

reference to Figures 20A and 20B, controller 834 provides a sequence of operating commands to the apertures 802_L and 802_R.

In step 874, a plurality of frames, each for a selected aperture and wavelength combination is detected. Controller 834 operates the image detector 812 so as to detect a plurality of frames, each respective of a selected aperture and wavelength combination.

Light rays 822 and 824 (Figure 20A) arrive from section 810A of object 810, pass through aperture 802_R, and are detected by detection element 808A, while light rays 826 and 828 arrive from section 810D, pass through aperture 802_R and are detected by detection element 808D. It is noted that in the present example, an imaging element (not shown) is introduced in the vicinity of multiple aperture 804. Hence, when aperture 802_R is open, the system 800 provides a right side view of the object 810.

Light rays 827 and 825 (Figure 20B) arrive from section 810A, pass through aperture 802_L and are detected by detection element 808A, while light rays 821 and 823 arrive from section 810D, pass through aperture 802_L and are detected by detection element 808D. Hence, when aperture 802_L is open, the system 800 provides a left side view of the object 810.

With reference to Figure 21A, rise 841_A provides a right side blue image (reference $806^R{}_B$ of Figure 20A), rise 841_B provides a right side green image (reference $806^R{}_G$ of Figure 20A), and rise 841_C provides a right side red image (reference $806^R{}_R$ of Figure 20A). Similarly, rise 841_D provides a left side blue image (reference $806^L{}_B$ of Figure 20B), rise 841_E provides a left side green image (reference $806^L{}_G$ of Figure 20B), and rise 841_F provides a left side red image (reference $806^L{}_R$ of Figure 20B). With reference to Figures 20A and 20B, image detector 812 detects the plurality of frames, and provides right and left output video for image processing.

In step 876, movement between the detector and the inspected organ, at selected frequencies is detected. This movement can be detected from movement of the endoscope, by means of a movement

detector, or by analyzing the detected images, where different color images exhibit different lines, with dramatic color shade changes. This information is utilized in the following step, for spatially correlating between images of different colors.

In step 878 a stereoscopic color image from the plurality of frames, according to their aperture origin is produced. With reference to Figures 20A and 20B, the controller 834 stores the detected images in storage unit 836. Image processor 838 retrieves the detected images from the storage unit 836, and constructs color stereoscopic images. Hence, the disclosed technique provides an additional way for detecting a color stereoscopic image, using a single image detector for both sides and all colors.

Reference is further made to Figure 21B, which is a schematic illustration of another timing sequence, in which controller 834 (Figure 20A) synchronizes the operation of illumination unit 830, apertures 802_L and 802_R, and image detector 812. Signal 840' represents the timing sequence of the left aperture 802_L. Signal 842' represents the timing sequence of the right aperture 802_R. Signal 844' represents the timing sequence of the blue light beam, produced by the illumination unit 830. Signal 846' represents the timing sequence of the green light beam, produced by the illumination unit 830. Signal 848' represents the timing sequence of the red light beam, produced by the illumination unit 830. Signal 841' represents the timing sequence of the image detector 812, where each image is downloaded therefrom.

Timing sequence 841' rises every time any of the rises of sequences 844', 846' and 848' intersects with a rise of either sequence 842' or sequence 840'. For example, rise $841'_A$ indicates a frame download of a blue light – right aperture combination, rise $841'_B$ indicates a frame download of a blue light – left aperture combination and rise $841'_C$ indicates a frame download of a green light – right aperture combination. Similarly, rise $841'_D$ indicates a frame download of a green light – left

aperture combination, rise 841'$_E$ indicates a frame download of a red light – right aperture combination and rise 841'$_F$ indicates a frame download of a blue light – left aperture combination.

Reference is further made to Figure 23, which is a schematic illustration of a timing scheme, for operating system 800 of Figures 20A and 20B, in accordance with a further embodiment of the disclosed technique. Signal 850 represents the timing sequence of the left aperture 802$_L$. Signal 852 represents the timing sequence of the right aperture 802$_R$. Signal 854 represents the timing sequence of the blue light beam. Signal 856 represents the timing sequence of the green light beam. Signal 858 represents the timing sequence of the red light beam. Signal 851 represents the timing sequence of the image detector 812, where each image is downloaded therefrom. As can be seen in Figure 23, the timing scheme is asymmetric, where the green light beam is activated for a time period which is twice the time period of either the red light beam or the blue light beam. Signal 851 corresponds to this arrangement and provides a green image download rise (references 851$_B$ and 851$_E$), after a time period which is twice as long with comparison to red image download rises (references 851$_C$ and 851$_F$) or blue image download rises (references 851$_A$ and 851$_D$).

Reference is further made to Figure 24, which is a schematic illustration of a timing scheme, for operating system 800 of Figures 20A and 20B, in accordance with another embodiment of the disclosed technique. Signal 860 represents the timing sequence of the left aperture 802$_L$. Signal 862 represents the timing sequence of the right aperture 802$_R$. Signal 864 represents the timing sequence of the magenta light beam. Signal 866 represents the timing sequence of the yellow light beam. Signal 868 represents the timing sequence of the cyan light beam. As can be seen in Figure 24, the timing scheme addresses an alternate wavelength scheme and is also asymmetric.

It is noted that a mechanical multi-wavelength illumination unit such as described in the prior art, can be used for implementing the disclosed technique. However, such a system significantly reduces the capability of the user to control illumination duration, wavelength ratio and detection timing, such as described herein above.

The disclosed technique incorporates even more advanced aspects, which provide automatic image translation correction, based on correlation between the two detected images. When the endoscope is handheld, it is subjected to the vibration of the human hand, which is in the order of 10 Hz, at an angular amplitude of 1 degree. This phenomenon causes a blur of areas, where different colors intersect, and is also known as the "between color field blur" effect. It is noted that any movement between the image detector and the inspected organ can cause this phenomenon, provided it occurs at particular frequencies, defined by the structure and the manner of operation of the system.

With reference to Figures 20A and 20B, since the information retrieved from image detector 812 relates to specific colors, then controller 834 can correlate between such single color images to determine the ΔX and ΔY to the subsequent color, and hence compose and produce an un-blurred color image. Due to the vibrations of the human hand, while image detector 812 is substantially stationary relative to object 810, the displayed stereoscopic image of object 810 is blurred. In order to mitigate this problem, and provide a blur-free stereoscopic image of object 810 to the viewer, movement detector 230 (Figure 2), is incorporated with system 200, and movement detector 814 is incorporated with system 800 (Figure 20A).

Reference is now made to Figures 25A, 25B, 25C, 26A, 26B and 26C and again to Figure 2. Figure 25A is a schematic illustration of an object, generally referenced 766, and a sensor assembly generally referenced 768, when the sensor assembly is located at an initial position with respect to the object. Figure 25B is a schematic illustration of the

object and the sensor assembly of Figure 25A, when the sensor assembly has moved to a new position. Figure 25C is a schematic illustration of the object and the sensor assembly of Figure 25A, when the sensor assembly has moved to another position. Figure 26A is a schematic illustration of a detected image, generally referenced 770, as detected by sensor assembly of Figure 25A, and a respective displayed image, generally referenced 772, in accordance with a further embodiment of the disclosed technique. Figure 26B is a schematic illustration of a detected image, generally referenced 780, as detected by sensor assembly of Figure 25B, and a respective displayed image, generally referenced 774. Figure 26C is a schematic illustration of a detected image, generally referenced 782, as detected by the sensor assembly of Figure 25C, and a respective displayed image, generally referenced 776.

The foregoing description relates to one aspect of the disclosed technique, in which a stereoscopic image of an object is captured by a sensor array through a lenticular lens layer (i.e., each captured image includes all the primary colors of the color palette, such as RGB, CYMG, and the like). It is noted that the movement is determined such that it has a constant average (e.g., vibrating about a certain point).

With reference to Figures 25A and 26A, the center of sensor assembly 768 is located at a point O_1 relative to object 766. Sensor assembly 768 detects detected image 770 (Figure 26A) of object 766, where the detected image 770 is composed for example, of four hundred pixels (i.e., a 20X20 matrix). Each pixel is designated by $P_{m,n}$ where m is the row and n is the column of detected image 770. For example, pixel $778_{1,1}$ is located in the first row and the first column of detected image 770, pixel $778_{1,2}$ is located in the first row and the second column, and pixel $778_{20,20}$ is located in row twenty and column twenty. Processor 208 (Figure 2) selects pixels $778_{3,3}$ through $778_{18,18}$ (i.e., a total of 16X16=256 pixels) to display the sub-matrix 772 on stereoscopic display 214 (Figure 2), while the center of sensor assembly 768 is located at point O_1.

With reference to Figure 25B and 26B, due to the vibrations of the human hand, the center of sensor assembly 768 has moved to a point O_2 relative to object 766. Point O_2 is located a distance ΔX_1 to the right of point O_1 and a distance ΔY_1 below point O_1. In this case the length of ΔX_1 is equal to the horizontal width of two pixels of detected image 780, and the length ΔY_1 is equal to the vertical height of minus two pixels of detected image 780. Movement detector 230 (Figure 2) detects the movement of sensor assembly 768 from point O_1 to point O_2, and sends a signal respective of this movement, to processor 208.

With reference to Figure 26B, the image of the object section that was captured by sub-matrix 772, is now captured by a sub-matrix 774, which is shifted two pixels up and two pixels to the left. Hence, displaying sub-matrix 774, compensates for the movement of sensor assembly 768. For this purpose, processor 208 selects pixels $778_{1,1}$ through $778_{16,16}$ of detected image 780, for sub-matrix 774. Despite the movement of sensor assembly 768, the images of sub-matrices 772 and 774 are substantially of the same area, and therefore the user does not realize that sensor assembly 768 has moved from point O_1 to point O_2.

With reference to Figures 25C and 26C, the center of sensor assembly 768 has moved from point O_1 to a point O_3 relative to object 766. Point O_3 is located a distance ΔX_2 to the left of point O_1 and a distance ΔY_2 above point O_1. In this case the length of ΔX_2 is equal to the horizontal width of minus two pixels of detected image 782, and the length ΔY_2 is equal to the vertical height of one pixel of detected image 782. Movement detector 230 detects the movement of sensor assembly 768 from point O_1 to point O_3, and sends a signal respective of this movement, to processor 208.

With reference to Figure 26C, the image of the object section that was captured by sub-matrix 772, is now captured by a sub-matrix 776, which is shifted one pixel up and two pixels to the left. Hence, displaying sub-matrix 774, compensates for the movement of sensor assembly 768

two pixels to the left and one pixel up. For this purpose, processor 208 selects pixels $778_{5,4}$ through $778_{20,19}$ of detected image 782, for sub-matrix 776. Despite the movement of sensor assembly 768, the images of displayed images 772 and 776 are identical, and therefore the user does not realize that sensor assembly 768 has moved from point O_1 to point O_3. Therefore, by incorporating movement detector 230 with sensor assembly 768, the viewer views a blur-free stereoscopic color image of object 766, despite the vibrations of sensor assembly 768 caused by the human hand.

It is noted that processor 208 processes the detected images 780 and 782, if the dimensions ΔX_1, ΔX_2, ΔY_1 and ΔY_2 are of the order of A, the amplitude of vibrations of the human hand and in the appropriate frequency. In general, processor 208 performs the compensation process, for a plurality of captured images, as long as the detected movement, is maintained about a certain average point ($X_{AVERAGE}$,$Y_{AVERAGE}$). When one of the average values $X_{AVERAGE}$ and $Y_{AVERAGE}$ changes, then processor 208 initiates a new compensation process around the updated average point, accordingly.

Reference is now made to Figures 25D, 25E, 25F, 27A, 27B, 27C, 27D, 27E, 27F and again to Figures 20A, 20B, 25A, 25B and 25C. Figure 25D is a schematic illustration of the object and the sensor assembly of Figure 25A, when the sensor assembly has moved to a further new position. Figure 25E is a schematic illustration of the object and the sensor assembly of Figure 25A, when the sensor assembly has moved to another new position. Figure 25F is a schematic illustration of the object and the sensor assembly of Figure 25A, when the sensor assembly has moved to a further new position. Figure 27A is a schematic illustration of a sub-matrix, generally referenced 1064, in accordance with another embodiment of the disclosed technique, when the sensor assembly is at a location illustrated in Figure 25A. Figure 27B is a schematic illustration of a sub-matrix, generally referenced 1066, when the sensor assembly is at a location illustrated in Figure 25B. Figure 27C is a

schematic illustration of a sub-matrix, generally referenced 1068, when the sensor assembly is at a location illustrated in Figure 25C. Figure 27D is a schematic illustration of a sub-matrix, generally referenced 1070, when the sensor assembly is at a location illustrated in Figure 25D. Figure 27E is a schematic illustration of a sub-matrix, generally referenced 1072, when the sensor assembly is at a location illustrated in Figure 25E. Figure 27F is a schematic illustration of a sub-matrix, generally referenced 1074, when the sensor assembly is at a location illustrated in Figure 25F.

Image processor 838 (Figure 20A), selects each of sub-matrices 1064, 1066 and 1068 from detected images 1052, 1054 and 1056, respectively, as described herein above in connection with Figures 26A, 26B and 26C. Analogously, image processor 838 selects each of sub-matrices 1070, 1072 and 1074 from detected images 1058, 1060 and 1062, respectively, when the center of sensor assembly 768 is directed to each of the points O_4, O_5, and O_6, respectively. For example, when the center of sensor assembly 768 is directed to point O_4, which is located to the right and above point O_1, image processor 838 selects sub-matrix 1070 (Figure 27D). When the center of sensor assembly 838 is directed to point O_5 directly below point O_1, image processor 838 selects sub-matrix 1072 (Figure 27E). When the center of sensor assembly 838 is directed to point O_6 directly above point O_1, image processor 838 selects sub-matrix 1074 (Figure 27F).

In the following description, object 810 (Figures 20A and 20B) and object 766 (Figure 25A) are used interchangeably, although they both represent the same object. Object 810 is described in connection with multiple aperture 804 and illumination unit 830, while object 766 is described in connection with the location of sensor assembly 768 relative thereto. It is noted that during the time interval in which the opening of multiple aperture 804 switches from aperture 802_R (Figure 20A), to aperture 802_L (Figure 20B), sensor assembly 768 moves relative to object 766, due to the vibrations of the human hand. Thus, for example, sub-

matrix 1064 (Figure 27A) represents a right view image of object 810 corresponding to the image which image processor 838 captures, when aperture 802_R is open. On the other hand, sub-matrix 1066 (Figure 27B) represents a left view image of object 766, when aperture 802_L is open.

Furthermore, the color of detected images 1052, 1054, 1056, 1058, 1060, and 1062 changes as described herein above for example in connection with Figure 21B. Image processor 838 receives download image $841'_A$, and selects sub-matrix 1064 (Figure 27A), which is a right view image of object 766 (Figure 25A) in blue, when the center of sensor assembly 768 is directed to point O_1.

While multiple aperture 804 switches to aperture 802_L, the center of sensor assembly 768 (Figure 25B) directs to point O_2 (Figure 25B), and image processor 838 receives download image $841'_B$. Since the center of sensor assembly 768 is directed to point O_2 (Figure 25B), then image processor 838 selects sub-matrix 1066 (Figure 27B) which represents a left view image of object 810 in blue. Analogously, sub-matrix 1068 (Figure 27C) represents a green right view image of object 766 (download image $841'_C$), when the center of sensor assembly 768 is directed to point O_3 (Figure 25C). Sub-matrix 1070 (Figure 27D) represents a green left view image of object 766 (download image $841'_D$), when the center of sensor assembly 768 directs to point O_4 (Figure 25D). Sub-matrix 1072 (Figure 27E) represents a red right view image of object 766 (download image $841'_E$), when the center of sensor assembly 768 directs to point O_5 (Figure 25E). Sub-matrix 1074 (Figure 27F) represents a red left view image of object 766 (download image $841'_F$), when the center of sensor assembly 768 directs to point O_6 (Figure 25F).

According to Figure 21A, a stereoscopic display unit (not shown) displays sub-matrices 1064, 1066, 1068, 1070, 1072 and 1074 in sequence. Sub-matrices 1064, 1068 and 1072 are the right side views of substantially the same area of object 766, which together compose a right side color image of the object 766. Sub-matrices 1066, 1070 and 1074 are

the left side views of substantially the same area of object 766, which together compose a left side color image of the object 766. The stereoscopic display unit alternately displays the right view image and the left view image of substantially the same area of object 766. Thus, system 800 maintains a stable image of object 766, which does not exhibit any change in the location of object 766 as displayed on the stereoscopic display unit, despite the movement of sensor assembly 768 due to the vibrations of the human hand.

For example, image processor 838 selects sub-matrices 1064, 1068 and 1072 (Figures 27A, 27C and 27E, respectively), and the stereoscopic display (not shown), sequentially displays the same image in blue, green and red, respectively. Thus, the stereoscopic display presents a stable right side image of the object in full color, to the right eye. Similarly, the stereoscopic display sequentially displays sub-matrices 1066, 1070 and 1074 (Figures 27B, 27D and 27F, respectively), wherein the color of each sub-matrix sequentially changes from blue to green to red, respectively. In this manner, the stereoscopic display presents a stable left side image of the object in full color, to the left eye. Thus, the user views a stable full color stereoscopic image of the object, despite the movement of the endoscope due to the vibrations of the human hand.

It is noted that an RGB timing scheme can be employed. In this case, the stereoscopic display displays the sub-matrices in a sequence of right-red, left-green, right-blue, left-red, right-green and left-blue.

It is noted that the sequence of Figures 27A, 27B, 27C, 27D, 27E and 27F is cyclically repeated during the imaging process of the object. Other timing schemes can be employed where the download image trigger signal is used for acquiring a reading from movement detector 814, for the detected image. Examples for such timing schemes are illustrated in Figures 23, 24, and 21A.

In accordance with another aspect of the disclosed technique, there is thus provided an edible capsule wirelessly incorporated with a

control unit, for producing real time stereoscopic images of the digestive system of a patient while the capsule moves through the digestive system. The capsule further includes a plurality of compartments, for either dispensing chemical substances in the digestive system or collecting enteric substances from the digestive system, according to respective commands wirelessly transmitted from the control unit to the capsule.

Reference is now made to Figure 28, which is a schematic illustration of an imaging system, generally referenced 880, constructed and operative in accordance with a further embodiment of the disclosed technique. System 880 includes a capsule 882 and a control unit 884. Capsule 882 includes a stereoscopic sensor assembly in the form of a lenticular lens layer 886 attached to a sensor array 888, a power supply 890, a processor 892, a memory unit 894, a transceiver 898, a light source 912, a light dispersing unit 918 and an optical assembly 910. Control unit 884 includes a transceiver 900, an image processing system 902 and a stereoscopic display 904. Lenticular lens layer 886, sensor array 888 and light source 912 are generally similar to lenticular lens layer 222 (Figure 2), light sensor array 220 and light source 206, respectively, as described herein above. It is noted that stereoscopic display 904 can include stereoscopic goggles, a stereoscopic display unit, volumetric three-dimensional display, and the like.

Light dispersing unit 918 is in the form of an annular body made of a material which conveys beam of light there through, such as plastic, glass, and the like. Light dispersing unit 918 conveys and disperses the light beams which light source 912 emits. Light dispersing unit 918 surrounds the sensor assembly completely, thereby illuminating an object 908. Alternatively, the light dispersing unit can surround only part of the sensor assembly. Sensor array 888 detects light in gray scale. Alternatively, a different sensor array can be employed which detects light in a color scale. Light source 912 emits light beams in a predetermined range of wavelengths. Alternatively, a different light source can be

employed, which emits at least two alternating beams of light, each in a different range of wavelengths.

Processor 892, memory unit 894 and transceiver 898 are coupled together through a common bus 906. Image processing system 902 of control unit 884 is coupled with transceiver 900 and with stereoscopic display 904. Optical assembly 910 is located distally in capsule 882 in a line of sight between object 908 and lenticular lens layer 886.

Power supply 890 is a battery, an electrical power generator which draws power from the heat of the body of the patient, and the like, which provides electrical power to components located in capsule 882. Lenticular lens layer 886 separates a right side image and a left side image of object 908 for sensor array 888, and sensor array 888 sends a combined image (e.g., of the right and left side images) to processor 892. Processor 892 captures the image detected by sensor array 888 and processes each image, such as by performing data compression operations, and the like. For this purpose, processor 892 employs memory unit 894. Processor 892, then sends the processed data to transceiver 898. Transceiver 898 transmits the processed data, to image processing system 902 via transceiver 900.

Image processing system 902 processes the data received from transceiver 900, and produces two matrices respective of each of the right side and left side images of object 908. Image processing system 902, then produces video signals respective of the two matrices. Image processing system 902 provides the video signals to stereoscopic display 904, which in turn produces a stereoscopic image of object 908.

It is noted that according to this aspect of the disclosed technique, capsule 882 provides a stereoscopic view of inner wall of digestive system of the patient, thus substantially assisting the treating physician to reach the correct and minimally invasive diagnosis. It is furthermore noted that according to another aspect of the disclosed

technique, processor 892 and memory unit 894 can be eliminated from capsule 882. In this case system 880 can still produce and display a stereoscopic image of object 908, although this stereoscopic image is of a lower quality.

Reference is now made to Figures 29, which is a schematic illustration of an imaging system, generally referenced 920, constructed and operative in accordance with another embodiment of the disclosed technique. System 920 includes a capsule 922 and a control unit 924.

Capsule 922 includes a stereoscopic sensor assembly in the form of a lenticular lens layer 926 attached to a sensor array 928, a power supply 930, a processor 934, an optical assembly 916, a light source 914 and a transceiver 932. Control unit 924 includes a transceiver 938, a memory unit 942, an image processing system 944 and a stereoscopic display 946. Processor 934 is coupled with sensor array 928 and with transceiver 932. Power supply 930 provides electrical power to all components located in capsule 922. Memory unit 942, image processing system 944, stereoscopic display 946 and transceiver 938 are coupled together via a common bus 948. Processor 934 receives data respective of the right side image and the left side image of an object 936 from sensor array 928, processes the data, and sends the data to transceiver 932. Transceiver 932 transmits the data to image processing system 944 via transceiver 938. Image processing system 944, in turn processes the data respective of the right side image and left side image, produces video signals respective of the right side image and the left side image of object 936, and transmits the video signals to stereoscopic display 946. Stereoscopic display 946, then provides a stereoscopic image of object 936.

It is noted that in this case capsule 922 includes a minimum number of components (i.e., lenticular lens layer 926, sensor array 928, power supply 930, transceiver 932, processor 934 and light source 914). Thus, capsule 922 can be much smaller in size than capsule 882 (Figure

28), while providing the same information about the digestive system of the patient. As a result, the electrical power requirements of capsule 922 are typically lower than that of capsule 882, thus enabling a reduction in the size of power supply 930, compared with power supply 890. Therefore the physical dimensions of capsule 922 can be further smaller than those of capsule 882.

Reference is now made to Figure 30, which is a schematic illustration of an imaging system, generally referenced 950, constructed and operative in accordance with a further embodiment of the disclosed technique. System 950 includes a capsule 952 and a control unit 954. Capsule 952 includes a plurality of dispensing compartments 956_A, a plurality of collection compartments 956_B, a transceiver 960, a processor 962, a power supply 964, a stereoscopic sensor assembly in the form of a lenticular lens layer 966 attached to a sensor array 968, a light source 982 and an optical assembly 980. Each of the dispensing compartment 956_A and collection compartment 956_B includes door mechanisms 958_A and 958_B, respectively. Control unit 954 includes a transceiver 970, a user interface 972, an image processing system 974 and a stereoscopic display 976. Dispensing compartment 956_A is designed to release a medical substance into the digestive system, as shown by an arrow 978_A. Collection compartment 956_B is designed to collect bodily substances from the digestive system, as shown by an arrow 978_B.

Transceiver 960, processor 962, power supply 964, lenticular lens layer 966, sensor array 968 and optical assembly 980 are similar to transceiver 932 (Figure 29), processor 934, power supply 930, lenticular lens layer 926, sensor array 928 and optical assembly 916, respectively. Transceiver 970, image processing system 974 and stereoscopic display 976 are likewise similar to transceiver 938, image processing system 944 and stereoscopic display 946, respectively. User interface 972 is an input device of the types known in the art, such as tactile, audio, visual, kinesthetic, and the like.

Processor 962 is coupled with sensor array 968, transceiver 960, power supply 964 and each of door mechanisms 958_A and 958_B. Image processing system 974 is coupled with stereoscopic display 976, user interface 972 and transceiver 970.

Initially, when the patient ingests capsule 952, dispensing compartment 956_A and collection compartment 956_B are closed. Dispensing compartment 956_A contains a medical substance, which is to be dispensed in a selected location within the digestive system. On the other hand, collection compartment 956_B is initially empty, in order to collect a bodily substance from a selected location within the digestive system of the patient.

When door mechanism 958_A opens, the medical substance is released form dispensing compartment 956_A. The amount of the medical substance released, can be controlled by controlling the opening time period of door mechanism 958_A. Thus, in order to release a required volume of the medical substance, door mechanism 958_A is opened for a selected time period, and then immediately closed.

Likewise, when door mechanism 958_B is opened, the bodily substances in the vicinity of capsule 952 fill collection compartment 956_B. Door mechanism 958_B can be left open for a selected period of time, in order to collect a selected amount of bodily substances. Door mechanism 958_B is then closed in order to keep the bodily substances within collection compartment 956_B. At a later stage during the treatment, capsule 952 is retrieved from the patient, door mechanism 958_B is opened, and the collected bodily substances are removed from collection compartment 956_B for testing the collected bodily substances.

Processor 962 can direct either of door mechanisms 958_A or 958_B to open or close. Each of the door mechanisms 958_A and 958_B includes a movable element (not shown), such as a shape memory element, a bi-metallic element, a micro-electromechanical system

(MEMS), and the like, which alternately opens and closes the respective door mechanism.

When capsule 952 moves within the digestive system of the patient, the physician views the stereoscopic image of the internal wall of the digestive system in real time, via stereoscopic display 976. When the physician determines that the medical substance has to be dispensed at a selected location, as viewed via stereoscopic display 976, she directs door mechanism 958_A via user interface 972, to open. The physician can direct user interface 972 to leave door mechanism 958_A open, for a selected period of time in order to dispense a selected volume of the medical substance.

When user interface 972 receives a command from the physician to open door mechanism 958_A, user interface 972 sends a respective signal to transceiver 970. Transceiver 970 in turn transmits the signal to transceiver 960, and processor 962 directs door mechanism 958_A to open according to another signal received from transceiver 960.

When the physician determines that bodily substances have to be collected from a selected location, for example, as viewed via stereoscopic display 976, she directs user interface 972 to open door mechanism 958_B. Door mechanism 958_B is closed after a predetermined time, either manually or automatically, during which a controlled amount of bodily substances enter collection compartment 956_B and fill collection compartment 956_B. The physician directs capsule 952 to activate door mechanism 958_B as described herein above in conjunction with activation of door mechanism 958_A.

It is noted that capsule 952 can include a plurality of dispensing compartments 956_A and a plurality of collection compartments 956_B. Thereby, the physician can direct capsule 952 to dispense different or the same medical substances, at one or different locations within the digestive system of the patient. For this purpose, processor 962 includes therein the addresses of each of the plurality of dispensing compartments. Thus, user

interface 972 can associate an activation command (i.e., open or close) with a selected dispensing compartment. Likewise, processor 962 includes the addresses of each of the collection compartments, wherein user interface 972 can associate an activation command with a selected collection compartment.

Reference is now made to Figure 31, which is a schematic illustration of a capsule, generally referenced 1000, constructed and operative in accordance with another embodiment of the disclosed technique. Capsule 1000 includes an optical assembly 1002, an upper mirror 1004, a lower mirror 1006, an upper sensor array 1008, a lower sensor array 1010, a processor 1012, a transceiver 1014, a light source 1020 and a power supply 1016. Upper mirror 1004 and lower mirror 1006 are each convex type mirrors. In general, these mirrors are each designed to project the image received from the optical assembly, onto the respective sensor array, and hence can assume other shapes, depending on the optical geometry of the system.

The detecting surfaces of upper sensor array 1008 and lower sensor array 1010 face opposite directions. Upper mirror 1004 faces the detecting surface of upper sensor array 1008, and lower mirror 1006 faces the detecting surface of lower sensor array 1010. Optical assembly 1002 is located between lower mirror 1006, upper mirror 1004, and an object 1018 such that optical assembly 1002 directs light beams from object 1018 to lower mirror 1006 and upper mirror 1004. Upper sensor array 1008 and lower sensor array 1010 are each coupled with processor 1012. Processor 1012 is further coupled with transceiver 1014.

Optical assembly 1002 directs the light beams from the upper view of object 1018, toward lower mirror 1006. Likewise, optical assembly 1002 directs the light beams from the lower view of object 1018, toward upper mirror 1004. Lower mirror 1006, then directs the upper view image of object 1018 toward lower sensor array 1010, and upper mirror 1004 directs the lower view image of object 1018 toward upper sensor array

1008. Thus, lower sensor array 1010 detects the upper view image of object 1018 and upper sensor array 1008 detects the lower view image of object 1018.

Processor 1012 processes the data which upper sensor array 1008 and lower sensor array 1010 produce, such as by performing data compression operations, discarding redundant data, and the like. Transceiver 1014 transmits the processed data to an image processing system (not shown) via a different transceiver (not shown). The image processing system produces video signals respective of the processed data, and a stereoscopic display (not shown) displays a stereoscopic image of object 1018. It is noted that the light beam configuration illustrated in Figure 31 is only an example (i.e., upper mirror 1004 and lower mirror 1006 are not restricted to convex type mirrors). Thus, according to this aspect of the disclosed technique, other types of mirrors can be employed.

Reference is now made to Figures 32A and 32B. Figure 32A is a schematic illustration of a capsule, generally referenced 1030, constructed and operative in accordance with a further embodiment of the disclosed technique. Figure 32B is an illustration of the capsule of Figure 32A, in a different detection mode.

Capsule 1030 includes a lens 1032, a stereoscopic sensor assembly in the form of a multiple aperture 1034 and a sensor array 1036, a processor 1038, a memory unit 1040, a transceiver 1042, an illumination unit 1046 and a power supply 1044. Multiple aperture 1034, sensor array 1036, processor 1038 and illumination unit 1046 are substantially similar to multiple aperture 804 (Figure 20A), image detector 812, controller 834 and illumination unit 830, respectively, as described herein above.

With reference to Figure 32A, illumination unit 1046 illuminates an object 1048, and lens 1032 focuses the light beams reflected by object 1048 on multiple aperture 1034. The lower portion of multiple aperture 1034 is closed, thus sensor array 1036 detects the upper view of object

1048. With reference to Figure 32B, the upper portion of multiple aperture 1034 is closed, wherein sensor array 1036 detects the lower view of object 1048. The upper and lower portions of multiple aperture 1034 alternately open and close, thereby allowing sensor array 1036 to detect alternately the upper and lower views of object 1048.

Processor 1038 operates multiple aperture 1034, sensor array 1036 and illumination unit 1046 as described herein above in connection with Figure 20A. Processor 1038 receives a sequence of images of object 1048, for example as illustrated in Figure 21A, from sensor array 1036 and sequentially stores the images in memory unit 1040. When memory unit 1040 contains a predetermined number of the sequential images, memory unit 1040 sends these images to transceiver 1042. Transceiver 1042 sends the images to an image processing system (not shown) via a different transceiver (not shown). The image processing system produces video signals respective of the images, and a stereoscopic display (not shown) displays a stereoscopic image of object 1048. It is noted that based on the type of illumination unit 1046 (i.e., color or monochrome), the stereoscopic display can display either a color or a monochromatic stereoscopic image of object 1048.

It will be appreciated by persons skilled in the art that the disclosed technique is not limited to what has been particularly shown and described here in above. Rather the scope of the disclosed technique is defined only by the claims which follow.

CLAIMS

1. System for producing a stereoscopic image of an object, and displaying the stereoscopic image, the system comprising:

    a capsule; and

    a control unit;

    said capsule comprising:

        a sensor assembly;

        a processor coupled with said sensor assembly;

        a capsule transceiver coupled with said processor;

        a light source; and

        a power supply for supplying electrical power to said capsule transceiver, said processor, said light source and to said sensor assembly,

    said control unit comprising:

        a control unit transceiver; and

        an image processing system coupled with said control unit transceiver,

    wherein, said sensor assembly detects said stereoscopic image, said processor captures said stereoscopic image, said capsule transceiver transmits said stereoscopic image to said control unit transceiver and said image processing system processes said stereoscopic image.

2. The system according to claim 1, wherein said capsule further comprises a memory unit coupled with said processor and with said capsule transceiver, said power supply supplying electrical power to said memory unit.

3. The system according to claim 1, wherein said control unit further comprises a memory unit coupled with said control unit transceiver and with said image processing system .

4. The system according to claim 1, wherein said capsule further comprises an optical assembly for focusing an image of said object on said sensor assembly.

5. The system according to claim 2, wherein said capsule further comprises an optical assembly for focusing an image of said object on said sensor assembly.

6. The system according to claim 3, wherein said capsule further comprises an optical assembly for focusing an image of said object on said sensor assembly.

7. The system according to claim 1, wherein said capsule further comprises a light dispersing unit which surrounds said sensor assembly completely.

8. The system according to claim 1, wherein said capsule further comprises a light dispersing unit which surrounds said sensor assembly partially.

9. The system according to claim 2, wherein said capsule further comprises a light dispersing unit which surrounds said sensor assembly completely.

10. The system according to claim 2, wherein said capsule further comprises a light dispersing unit which surrounds said sensor assembly partially.

11. The system according to claim 3, wherein said capsule further comprises a light dispersing unit which surrounds said sensor assembly completely.

12. The system according to claim 3, wherein said capsule further comprises a light dispersing unit which surrounds said sensor assembly partially.

13. The system according to claim 1, wherein said capsule further comprises at least one dispensing compartment.

14. The system according to claim 1, wherein said capsule further comprises at least one collecting compartment.

15. The system according to claim 13, wherein each of said at least one dispensing compartments comprises a door mechanism, and each of said door mechanisms is coupled with said processor.

16. The system according to claim 14, wherein each of said at least one collecting compartments comprises a door mechanism, and each of said door mechanisms is coupled with said processor.

17. The system according to claim 1, wherein said control unit furthermore comprises a user interface coupled with said control unit transceiver and with said image processing system.

18. The system according to claim 15, wherein each of said at least one dispensing compartments further contains a medical substance.

19. The system according to claim 16, wherein each of said at least one collecting compartments collects a bodily substance.

20. The system according to claim 18, wherein each of said at least one dispensing compartments releases a selected amount of said medical substance according to a command provided by said processor to said door mechanism .

21. The system according to claim 19, wherein each of said at least one collecting compartments collects a selected amount of said bodily substance according to a command which said processor provides said door mechanism.

22. The system according to claim 15, wherein each of said door mechanisms comprises a moving element for opening and closing each of said door mechanisms.

23. The system according to claim 16, wherein each of said door mechanisms comprises a moving element for opening and closing each of said door mechanisms.

24. The system according to claim 22, wherein the type of said moving element is selected from the list consisting of:

shape memory element;
bi-metallic element; and
micro-electromechanical system.

25. The system according to claim 23, wherein the type of said moving element is selected from the list consisting of:

shape memory element;
bi-metallic element; and

micro-electromechanical system.

26. The system according to claim 1, wherein said sensor assembly comprises:

lenticular lens layer, including a plurality of lenticular elements; and

light sensor array,

wherein each said lenticular elements is located in front of a selected group of said light sensors, thereby directing light from different directions to different light sensors within said selected group of said light sensors.

27. The system according to claim 26, wherein said light source produces at least two alternating beams of light, each said at least two alternating beams of light, each said alternating beams of light characterized as being in a different range of wavelengths.

28. The system according to claim 26, wherein said light source produces light in a predetermined range of wavelengths.

29. The system according to claim 26, wherein said light sensor array includes at least two groups of sensors, the sensors of each said group detect light in a different range of wavelengths.

30. The system according to claim 26, wherein said light sensor array includes a plurality of sensors, each said sensors detects light in a predetermined range of wavelengths.

31. The system according to claim 27, wherein each said different ranges of wavelengths associated with said light source, is selected from the list consisting of:

substantially visible red color light;
substantially visible green color light;
substantially visible blue color light;
substantially visible cyan color light;
substantially visible yellow color light;
substantially visible magenta color light;
substantially infra-red light;
substantially ultra-violet light; and
visible light.

32. The system according to claim 29, wherein each said different ranges of wavelengths associated with said sensors, is selected from the list consisting of:

substantially visible red color light;
substantially visible green color light;
substantially visible blue color light;
substantially visible cyan color light;
substantially visible yellow color light;
substantially visible magenta color light;
substantially infra-red light;
substantially ultra-violet light; and
visible light.

33. The system according to claim 30, wherein each said predetermined ranges of wavelengths associated with said sensors, is selected from the list consisting of:

substantially visible red color light;
substantially visible green color light;
substantially visible blue color light;
substantially visible cyan color light;
substantially visible yellow color light;

substantially visible magenta color light;
substantially infra-red light;
substantially ultra-violet light; and
visible light.

34. The system according to claim 26, wherein said light sensor array is a color red-green-blue (RGB) sensor array.

35. The system according to claim 26, wherein said light sensor array is a color cyan-yellow-magenta-green (CYMG) sensor array.

36. The system according to claim 26, wherein each said lenticular elements includes light directing means which distinguish between at least two directions of light.

37. The system according to claim 26, wherein each said lenticular elements includes light directing means, which distinguish between four directions of light.

38. The system according to claim 26, wherein each said lenticular elements is shaped in a general semi-cylindrical shape.

39. The system according to claim 26, wherein each said selected group of said light sensors includes an even number of light sensors.

40. The system according to claim 1, wherein said sensor assembly comprises:

at least two apertures, each said at least two apertures includes a light valve, each said light valves being operative to open at a different predetermined timing; and

a light sensor array,

wherein said light sensor array detects a plurality of images, each said images corresponds to an open state of a selected one of said light valves.

41. The system according to claim 40, wherein said light source produces at least two alternating beams of light, each alternating beams of light characterized as being in a different range of wavelengths.

42. The system according to claim 40, wherein said light source produces light in a predetermined range of wavelengths.

43. The system according to claim 40, wherein said light sensor array includes at least two groups of sensors, the sensors of each said group detect light in a different range of wavelengths.

44. The system according to claim 40, wherein said light sensor array includes a plurality of sensors, each said sensors detects light in a predetermined range of wavelengths.

45. The system according to claim 41, wherein each said different ranges of wavelengths associated with said light source, is selected from the list consisting of:

substantially visible red color light;
substantially visible green color light;
substantially visible blue color light;
substantially visible cyan color light;
substantially visible yellow color light;
substantially visible magenta color light;
substantially infra-red light;
substantially ultra-violet light; and
visible light.

46. The system according to claim 43, wherein each said different ranges of wavelengths associated with said sensors, is selected from the list consisting of:

substantially visible red color light;
substantially visible green color light;
substantially visible blue color light;
substantially visible cyan color light;
substantially visible yellow color light;
substantially visible magenta color light;
substantially infra-red light;
substantially ultra-violet light; and
visible light.

47. The system according to claim 44, wherein each said predetermined ranges of wavelengths associated with said sensors, is selected from the list consisting of:

substantially visible red color light;
substantially visible green color light;
substantially visible blue color light;
substantially visible cyan color light;
substantially visible yellow color light;
substantially visible magenta color light;
substantially infra-red light;
substantially ultra-violet light; and
visible light.

48. The system according to claim 40, wherein said light sensor array is a color red-green-blue (RGB) sensor array.

49. The system according to claim 40, wherein said light sensor array is a color cyan-yellow-magenta-green (CYMG) sensor array.

50. The system according to claim 41, wherein each said images corresponds to a predetermined combination of an open state of a selected one of said light valves and a selected one of said at least two alternating beams of light.

51. The system according to claim 40, wherein said light source surrounds said at least two apertures.

52. The system according to claim 40, wherein said light source directs light aside from said at least two apertures.

53. The system according to claim 1, wherein said sensor assembly comprises:

a lower light sensor array coupled with said processor;

an upper light sensor array coupled with said processor, an upper light sensor array detecting surface faces a direction opposite to the direction of a lower light sensor array detecting surface;

a lower mirror facing said lower light sensor array detecting surface;

an upper mirror facing said upper light sensor array detecting surface; and

an optical assembly located between said lower mirror, said upper mirror and said object for directing light beams from said object to said lower mirror and to said upper mirror, and

wherein each of said lower light sensor array and said upper light sensor array includes a plurality of light sensors, and

wherein said optical assembly directs at least one light beam from a first portion of said object to said lower mirror, and said optical

assembly directs at least one light beam from a second portion of said object to said upper mirror, and

wherein said lower mirror reflects said at least one light beam from said first portion to said lower light sensor array detecting surface, said upper mirror reflects said at least one light beam from said second portion to said upper light sensor array detecting surface, and

wherein said lower light sensor array detects an image of said first portion and said upper light sensor array detects an image of said second portion.

54. The system according to claim 53, wherein said light source produces at least two alternating beams of light, each said alternating beams of light characterized as being in a different range of wavelengths.

55. The system according to claim 53, wherein said light source produces light in a predetermined range of wavelengths.

56. The system according to claim 53, wherein said lower light sensor array includes at least two groups of sensors, the sensors of each said group detect light in a different range of wavelengths.

57. The system according to claim 53, wherein said upper light sensor array includes at least two groups of sensors, the sensors of each said group detect light in a different range of wavelengths.

58. The system according to claim 53, wherein said lower light sensor array includes a plurality of sensors, each said sensors detects light in a predetermined range of wavelengths.

59. The system according to claim 53, wherein said upper light sensor array includes a plurality of sensors, each said sensors detects light in a predetermined range of wavelengths.

60. The system according to claim 54, wherein each said different ranges of wavelengths associated with said light source, is selected from the list consisting of:

substantially visible red color light;
substantially visible green color light;
substantially visible blue color light;
substantially visible cyan color light;
substantially visible yellow color light;
substantially visible magenta color light;
substantially infra-red light;
substantially ultra-violet light; and
visible light.

61. The system according to claim 56, wherein each said different ranges of wavelengths associated with said sensors, is selected from the list consisting of:

substantially visible red color light;
substantially visible green color light;
substantially visible blue color light;
substantially visible cyan color light;
substantially visible yellow color light;
substantially visible magenta color light;
substantially infra-red light;
substantially ultra-violet light; and
visible light.

62. The system according to claim 57, wherein each said different ranges of wavelengths associated with said sensors, is selected from the list consisting of:

substantially visible red color light;
substantially visible green color light;
substantially visible blue color light;
substantially visible cyan color light;
substantially visible yellow color light;
substantially visible magenta color light;
substantially infra-red light;
substantially ultra-violet light; and
visible light.

63. The system according to claim 58, wherein each said predetermined ranges of wavelengths associated with said sensors, is selected from the list consisting of:

substantially visible red color light;
substantially visible green color light;
substantially visible blue color light;
substantially visible cyan color light;
substantially visible yellow color light;
substantially visible magenta color light;
substantially infra-red light;
substantially ultra-violet light; and
visible light.

64. The system according to claim 59, wherein each said predetermined ranges of wavelengths associated with said sensors, is selected from the list consisting of:

substantially visible red color light;
substantially visible green color light;

substantially visible blue color light;
substantially visible cyan color light;
substantially visible yellow color light;
substantially visible magenta color light;
substantially infra-red light;
substantially ultra-violet light; and
visible light.

65. The system according to claim 53, wherein said lower light sensor array is a color red-green-blue (RGB) sensor array.

66. The system according to claim 53, wherein said upper light sensor array is a color red-green-blue (RGB) sensor array.

67. The system according to claim 53, wherein said lower light sensor array is a color cyan-yellow-magenta-green (CYMG) sensor array.

68. The system according to claim 53, wherein said upper light sensor array is a color cyan-yellow-magenta-green (CYMG) sensor array.

69. The system according to claim 53, wherein said lower mirror is convex.

70. The system according to claim 53, wherein said upper mirror is convex.

71. The system according to claim 1, further comprising a stereoscopic display, coupled with said image processing system, for visually presenting said stereoscopic image.

72. The system according to claim 71, wherein said stereoscopic display is selected from the list consisting of:
    stereoscopic goggles;
    stereoscopic display unit; and
    volumetric three-dimensional display.

73. The system according to any of claims 1-72 substantially as described herein above.

74. The system according to any of the claims 1-72 substantially as illustrated in any of the drawings.

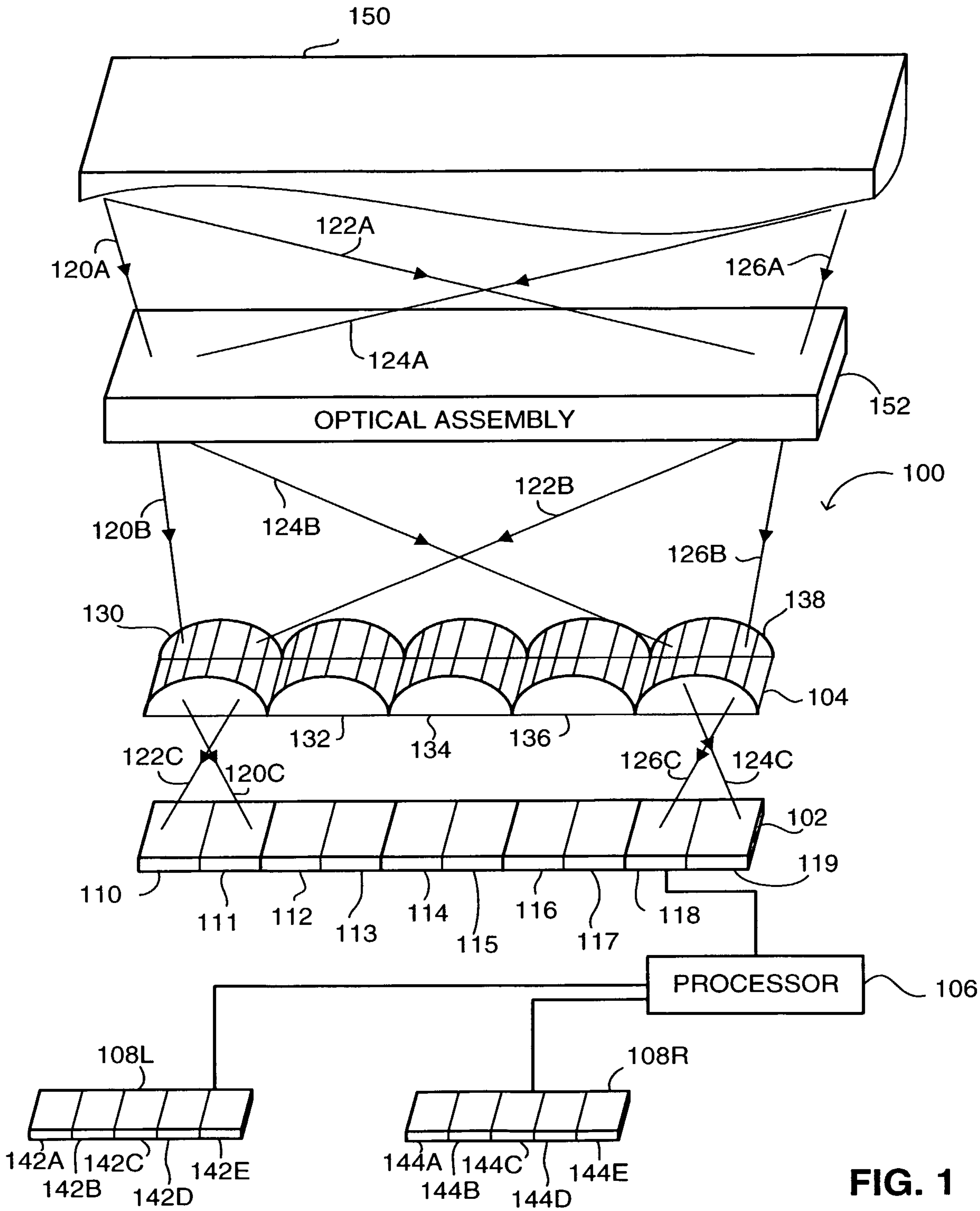

150
122A
120A
126A
124A
152
OPTICAL ASSEMBLY
100
122B
120B
124B
126B
130
138
104
132
134
136
122C
120C
126C
124C
102
119
110
111
112
113
114
115
116
117
118
PROCESSOR
106
108L
108R
142A
142B
142C
142D
142E
144A
144B
144C
144D
144E

FIG. 1

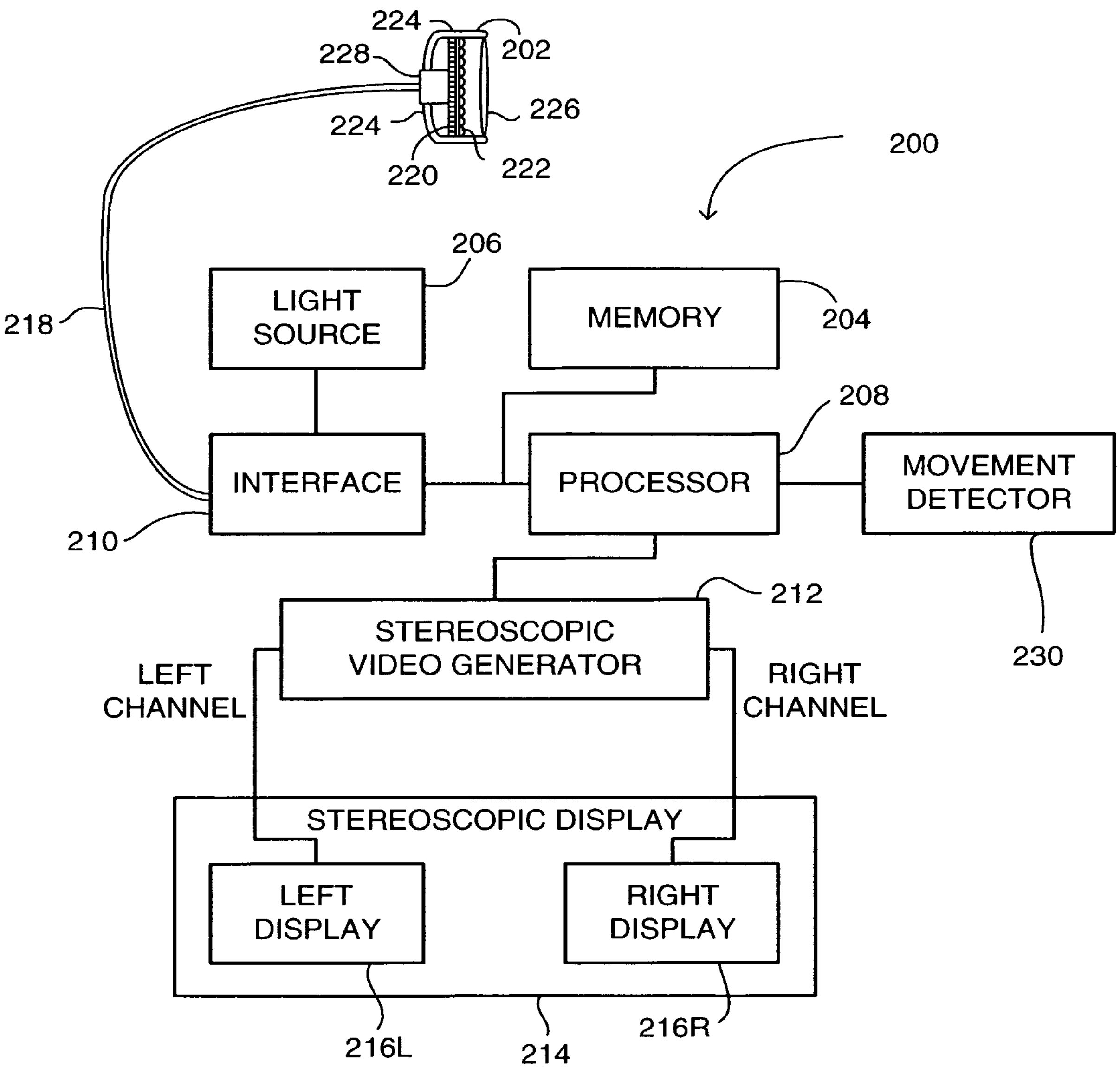

224
228
202
226
224
220
222
200
206
LIGHT SOURCE
MEMORY
204
218
208
INTERFACE
PROCESSOR
MOVEMENT DETECTOR
210
212
230
STEREOSCOPIC VIDEO GENERATOR
LEFT CHANNEL
RIGHT CHANNEL
STEREOSCOPIC DISPLAY
LEFT DISPLAY
RIGHT DISPLAY
216L
214
216R

FIG. 2

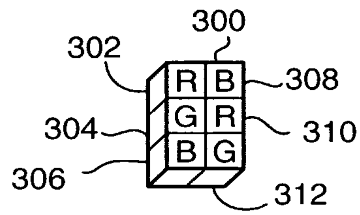


FIG. 3A

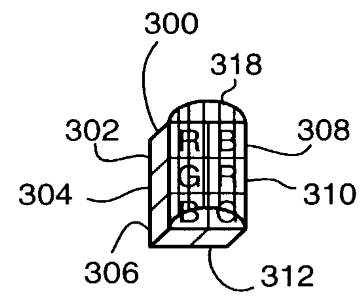


FIG. 3B

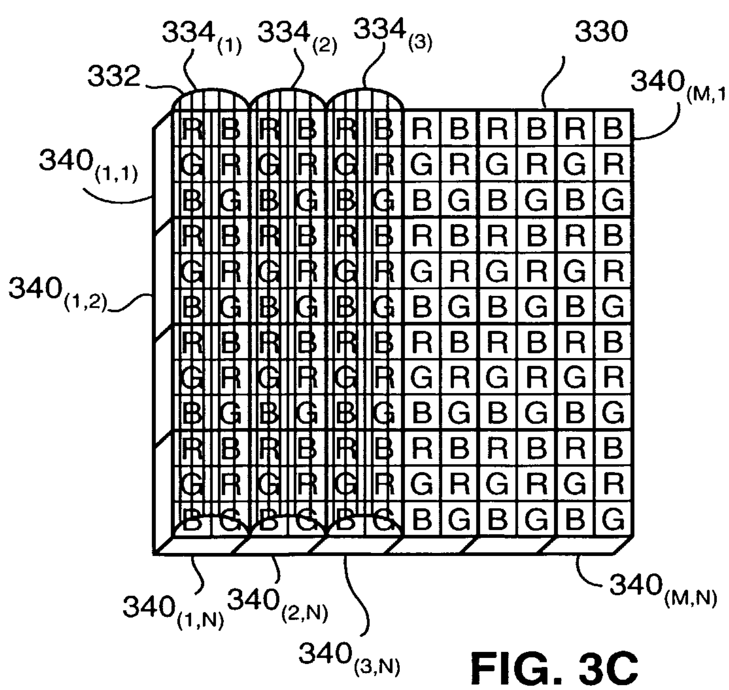


FIG. 3C

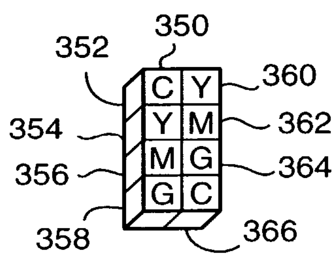


FIG. 4

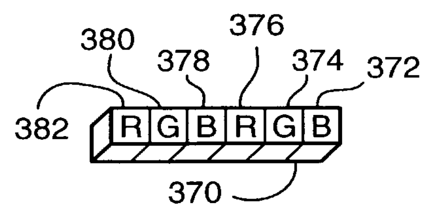


FIG. 5A

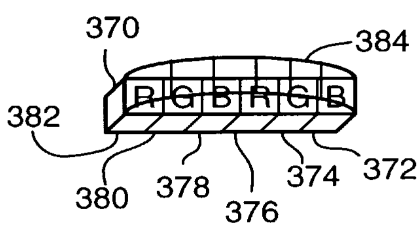


FIG. 5B

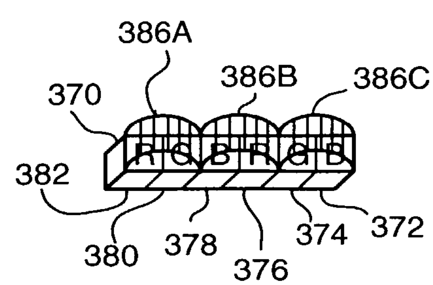


FIG. 5C

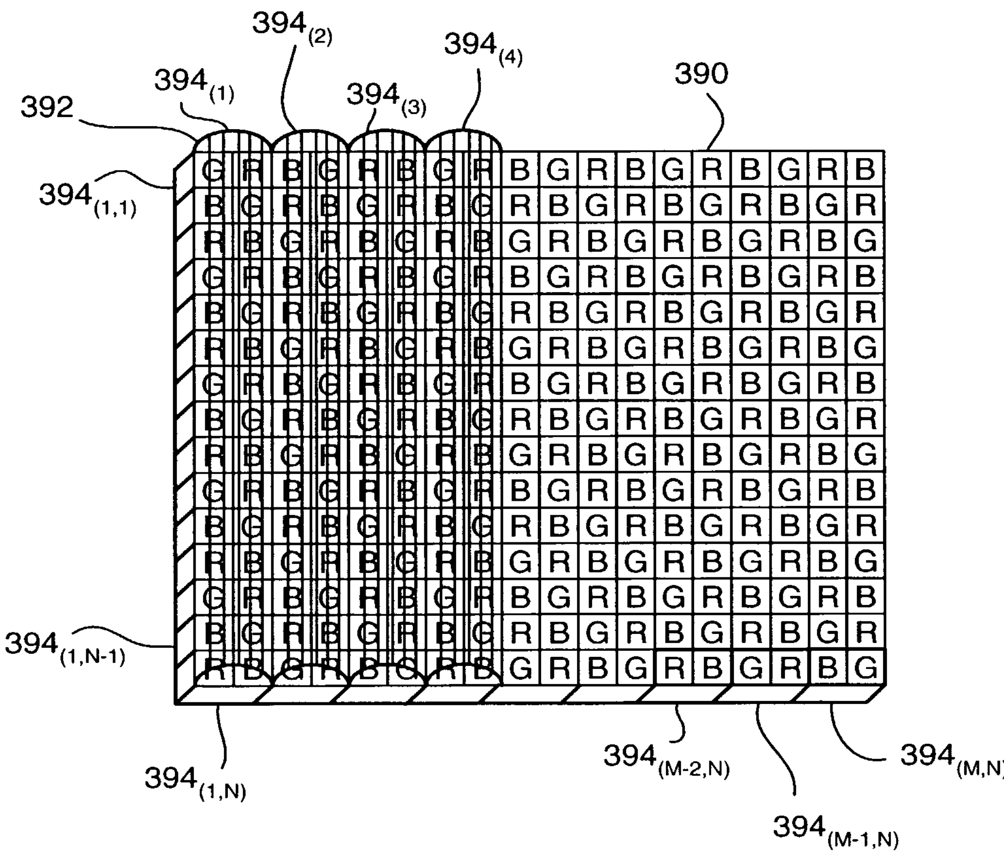

394(2)
394(4)
394(1)
394(3)
390
392
394(1,1)
394(1,N-1)
394(1,N)
394(M-2,N)
394(M,N)
394(M-1,N)

FIG. 6

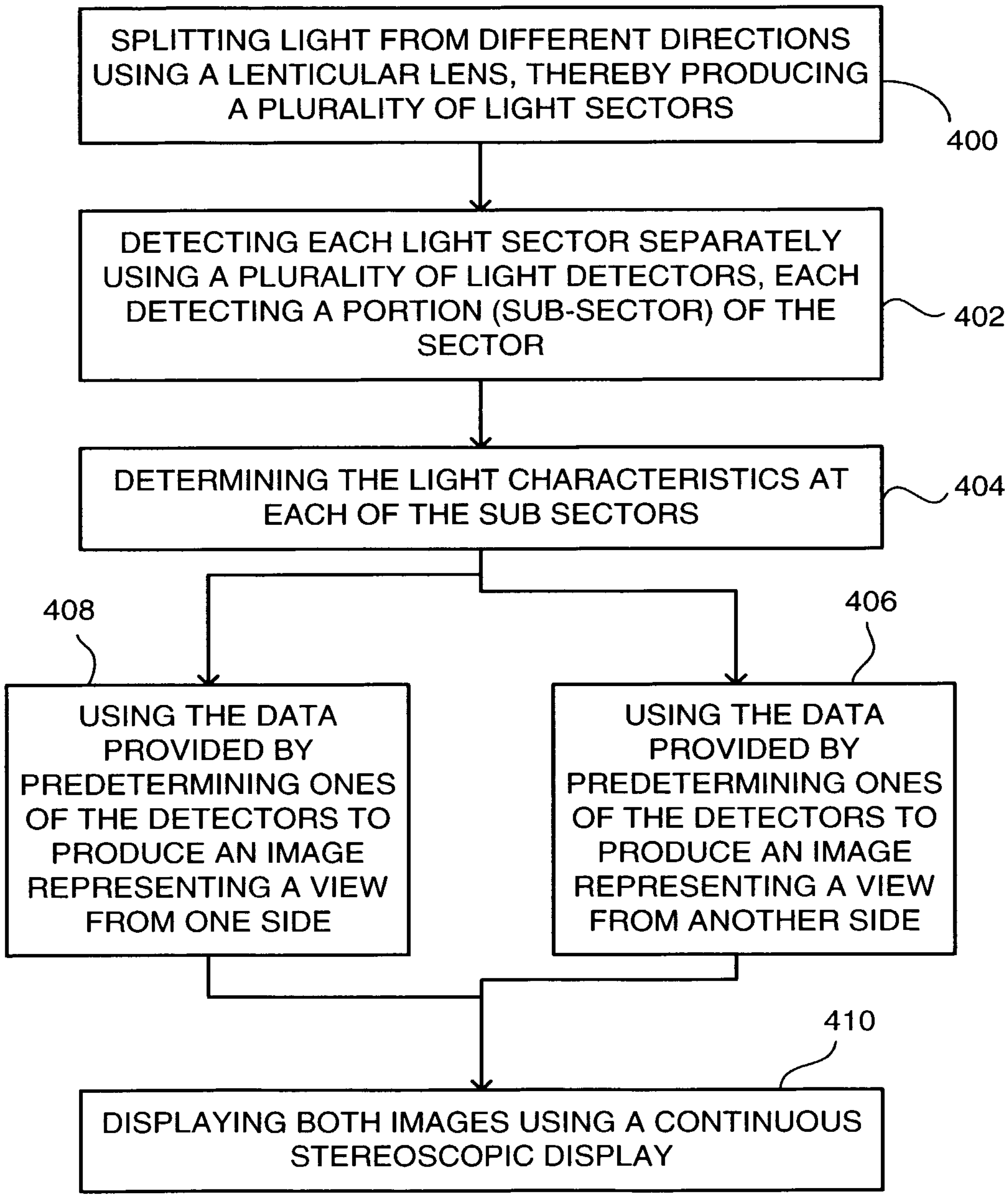
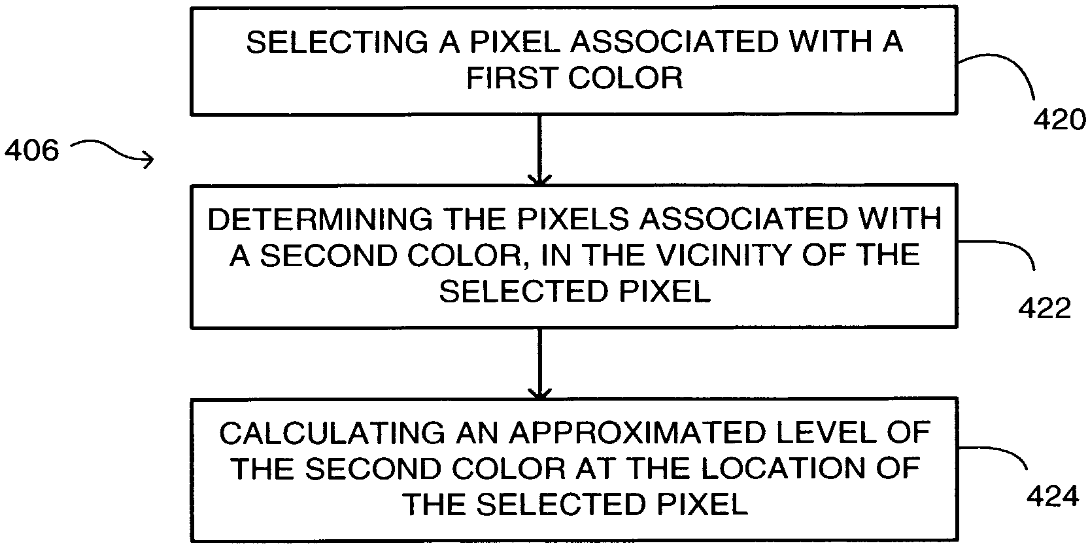
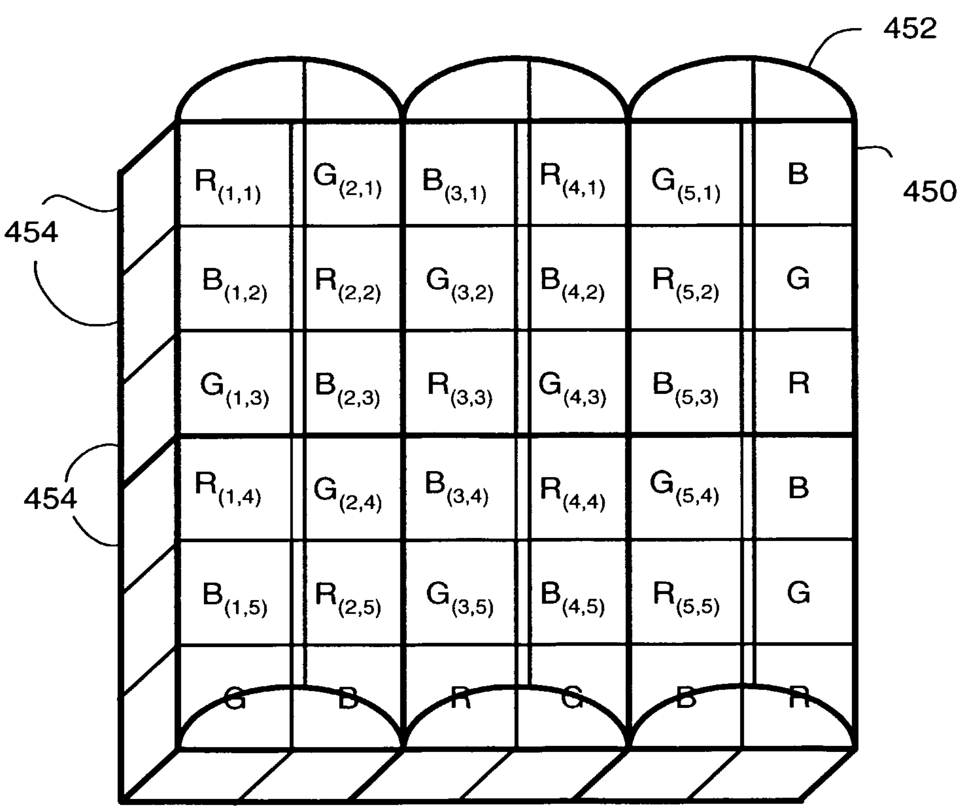

SPLITTING LIGHT FROM DIFFERENT DIRECTIONS USING A LENTICULAR LENS, THEREBY PRODUCING A PLURALITY OF LIGHT SECTORS
400
DETECTING EACH LIGHT SECTOR SEPARATELY USING A PLURALITY OF LIGHT DETECTORS, EACH DETECTING A PORTION (SUB-SECTOR) OF THE SECTOR
402
DETERMINING THE LIGHT CHARACTERISTICS AT EACH OF THE SUB SECTORS
404
408
406
USING THE DATA PROVIDED BY PREDETERMINING ONES OF THE DETECTORS TO PRODUCE AN IMAGE REPRESENTING A VIEW FROM ONE SIDE
USING THE DATA PROVIDED BY PREDETERMINING ONES OF THE DETECTORS TO PRODUCE AN IMAGE REPRESENTING A VIEW FROM ANOTHER SIDE
410
DISPLAYING BOTH IMAGES USING A CONTINUOUS STEREOSCOPIC DISPLAY

FIG. 7A



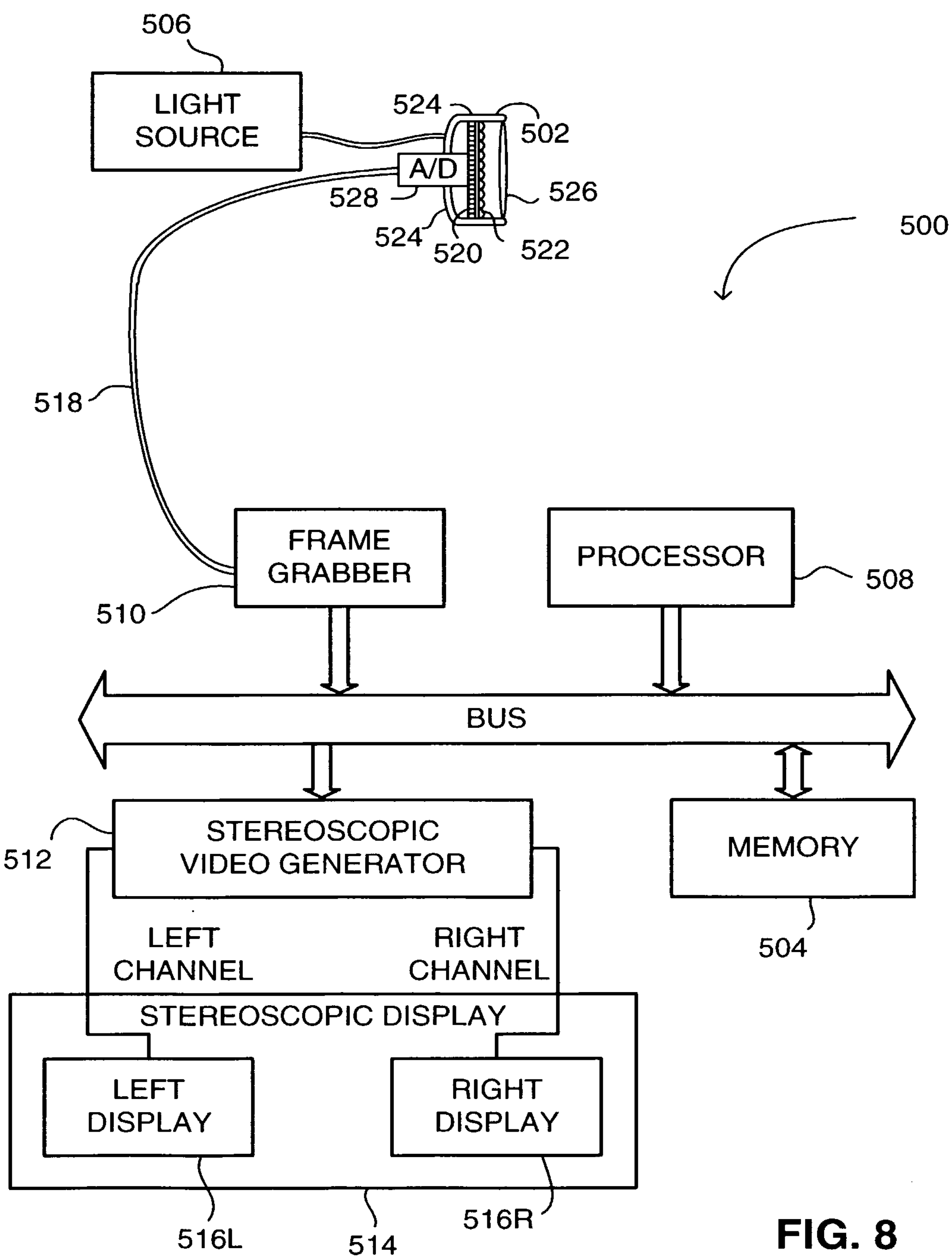
SELECTING A PIXEL ASSOCIATED WITH A FIRST COLOR
420
406
DETERMINING THE PIXELS ASSOCIATED WITH A SECOND COLOR, IN THE VICINITY OF THE SELECTED PIXEL
422
CALCULATING AN APPROXIMATED LEVEL OF THE SECOND COLOR AT THE LOCATION OF THE SELECTED PIXEL
424

FIG. 7B



452
450
454
454
$R_{(1,1)}$ $G_{(2,1)}$ $B_{(3,1)}$ $R_{(4,1)}$ $G_{(5,1)}$ B
$B_{(1,2)}$ $R_{(2,2)}$ $G_{(3,2)}$ $B_{(4,2)}$ $R_{(5,2)}$ G
$G_{(1,3)}$ $B_{(2,3)}$ $R_{(3,3)}$ $G_{(4,3)}$ $B_{(5,3)}$ R
$R_{(1,4)}$ $G_{(2,4)}$ $B_{(3,4)}$ $R_{(4,4)}$ $G_{(5,4)}$ B
$B_{(1,5)}$ $R_{(2,5)}$ $G_{(3,5)}$ $B_{(4,5)}$ $R_{(5,5)}$ G
G B R G B R

FIG. 7C



506
LIGHT SOURCE
524
502
A/D
528
526
524
520
522
500
518
FRAME GRABBER
PROCESSOR
508
510
BUS
STEREOSCOPIC VIDEO GENERATOR
MEMORY
512
LEFT CHANNEL
RIGHT CHANNEL
504
STEREOSCOPIC DISPLAY
LEFT DISPLAY
RIGHT DISPLAY
516L
514
516R

FIG. 8

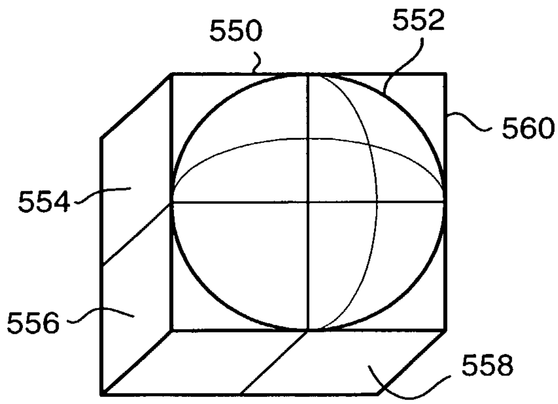


FIG. 9A

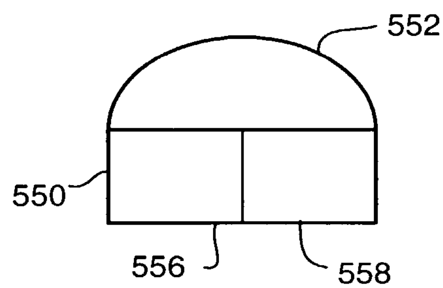


FIG. 9B

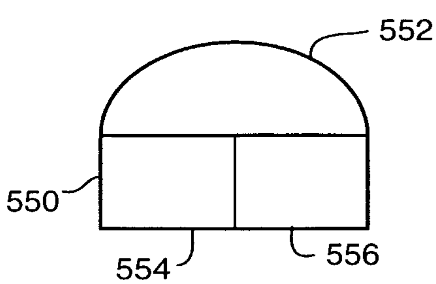


FIG. 9C

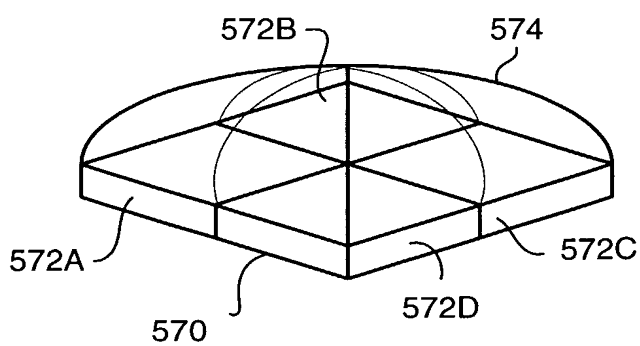


FIG. 10

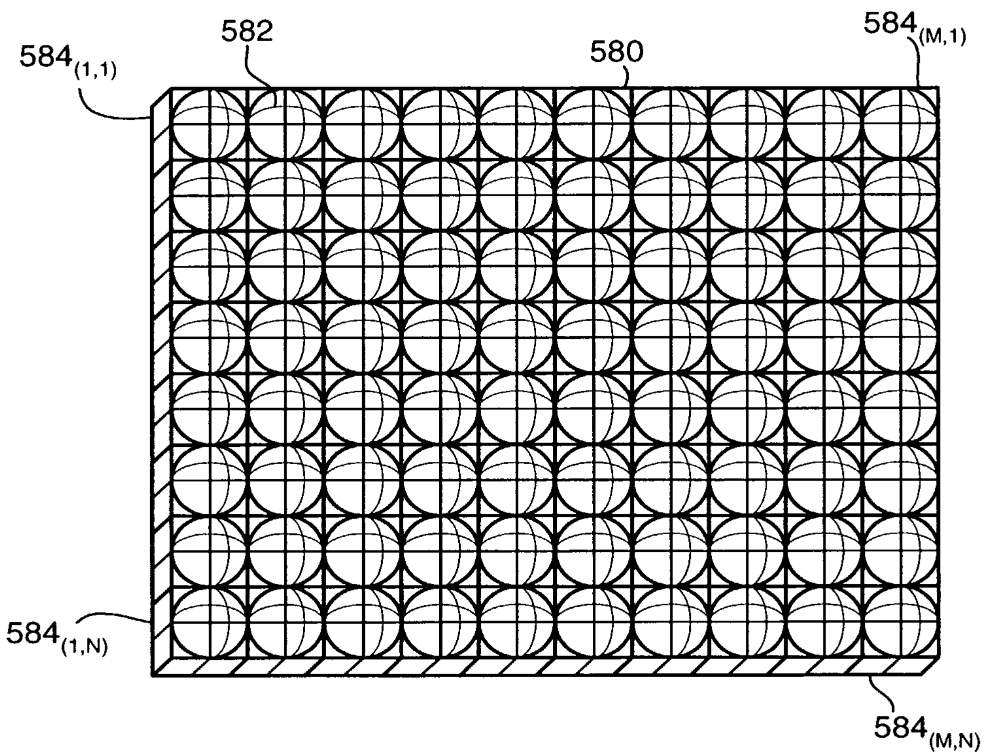
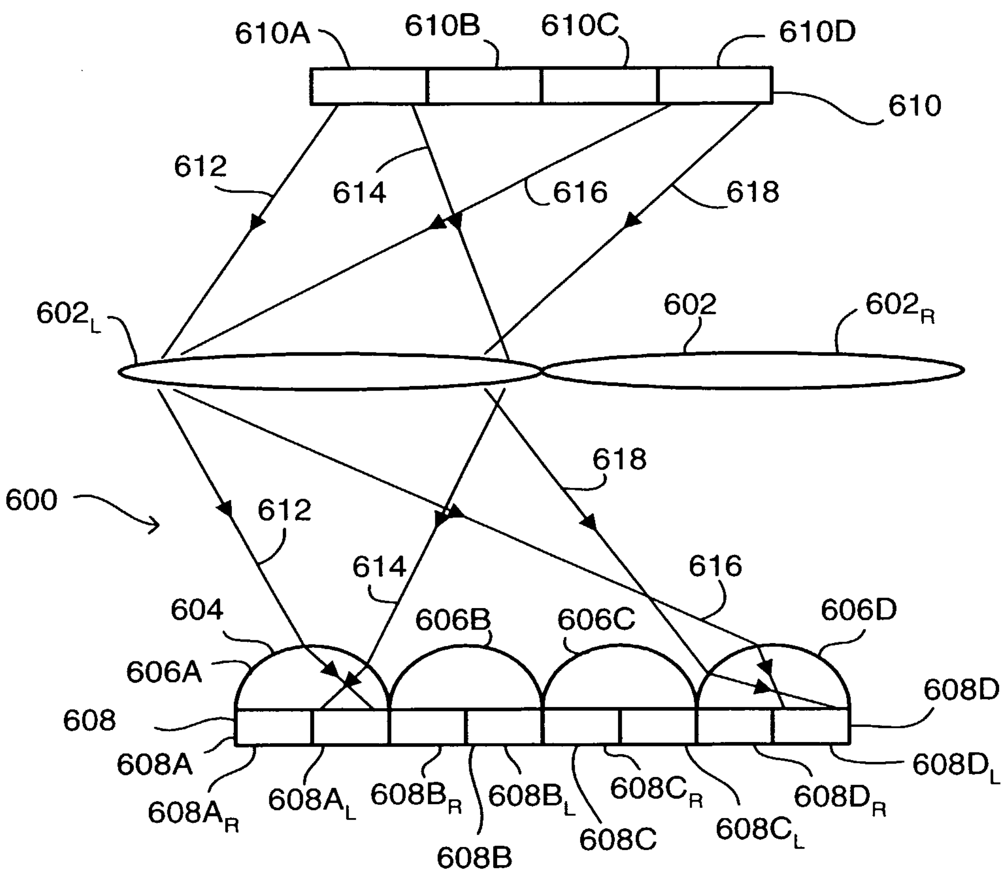
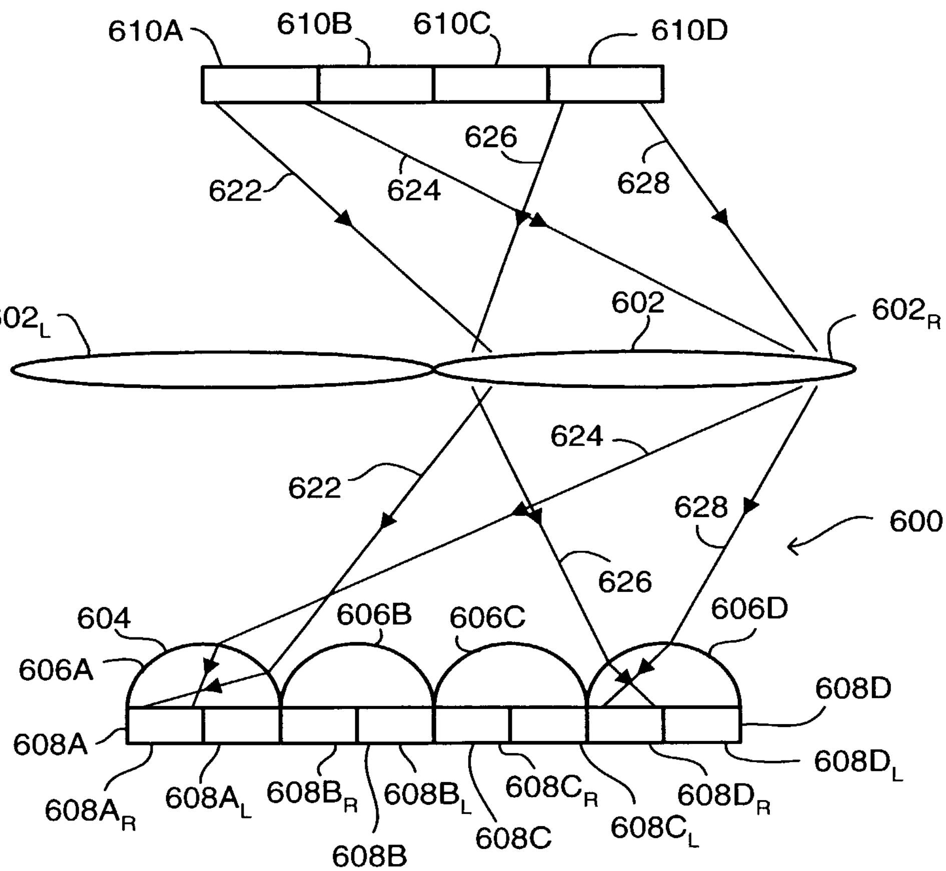


FIG. 11



610A
610B
610C
610D
610
612
614
616
618
602L
602
602R
600
612
618
614
616
604
606B
606C
606D
606A
608D
608
608A
608AR
608AL
608BR
608BL
608B
608C
608CR
608CL
608DR
608DL

FIG. 12A


610A
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610C
610D
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624
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628
602L
602
602R
622
624
628
626
600
604
606A
606B
606C
606D
608A
608D
608AR
608AL
608BR
608B
608BL
608C
608CR
608CL
608DR
608DL

FIG. 12B

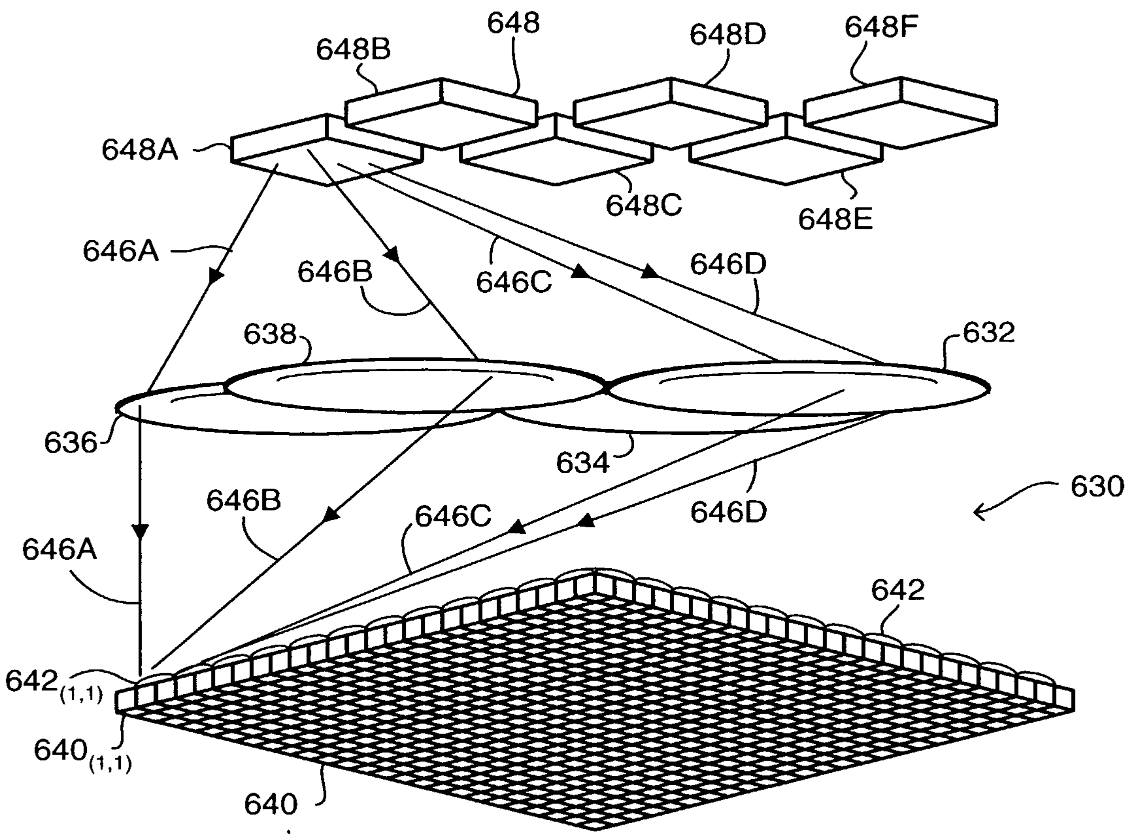

648
648B
648D
648F
648A
648C
648E
646A
646B
646C
646D
638
632
636
634
646B
646C
646D
630
646A
642
$642_{(1,1)}$
$640_{(1,1)}$
640

FIG. 13

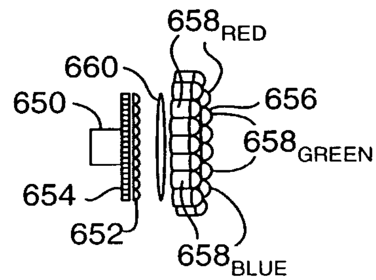


FIG. 14A

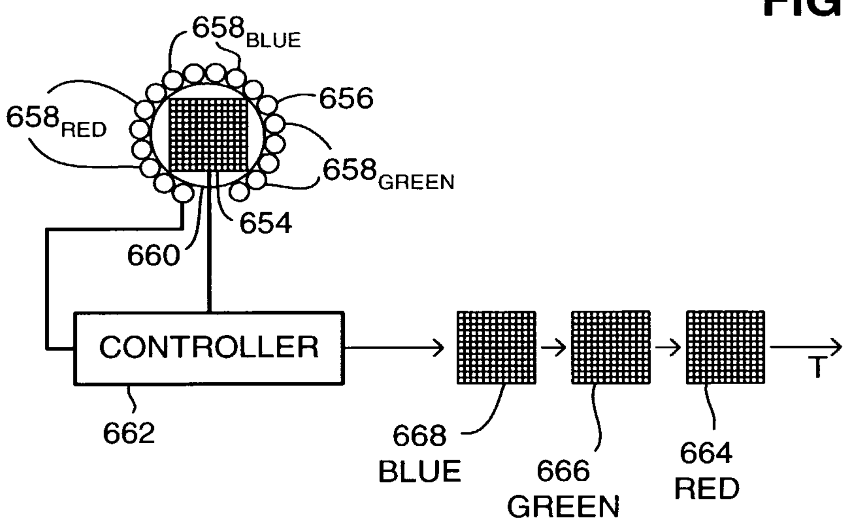


FIG. 14B

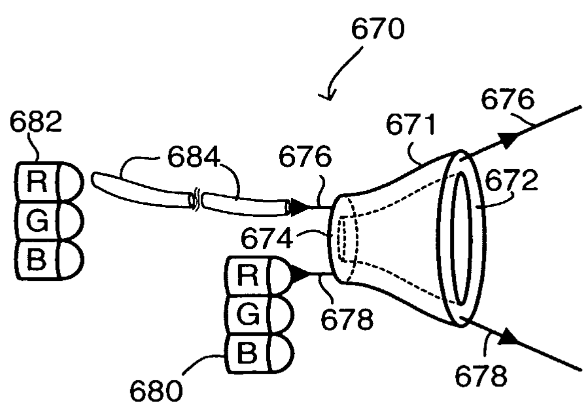


FIG. 15

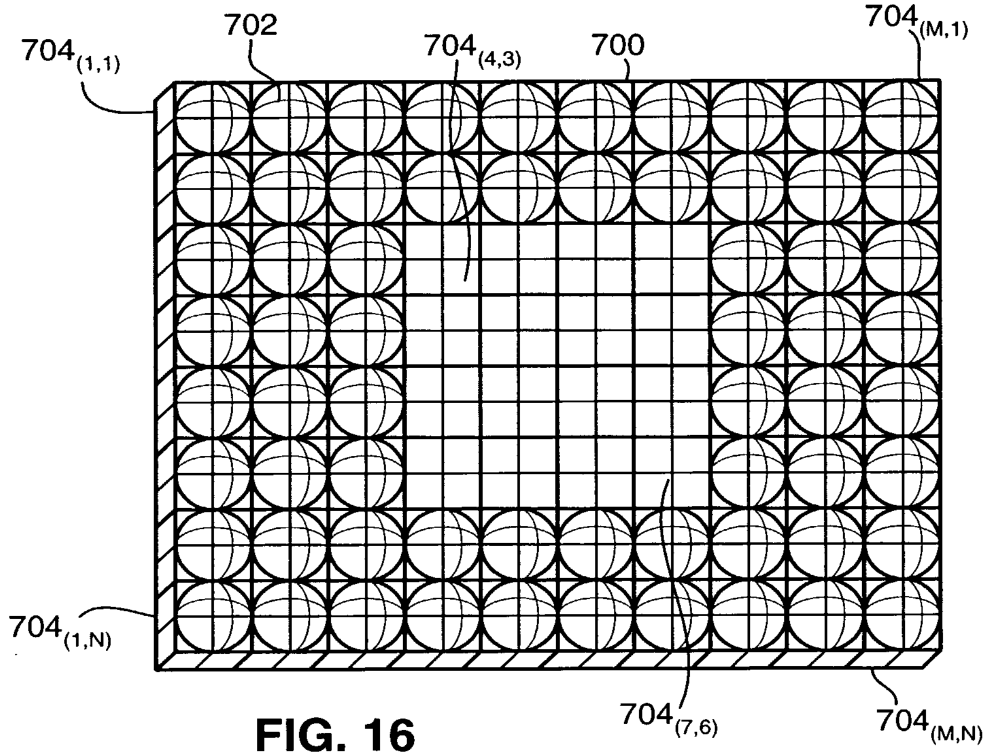

$704_{(1,1)}$
702
$704_{(4,3)}$
700
$704_{(M,1)}$
$704_{(1,N)}$
$704_{(7,6)}$
$704_{(M,N)}$

FIG. 16

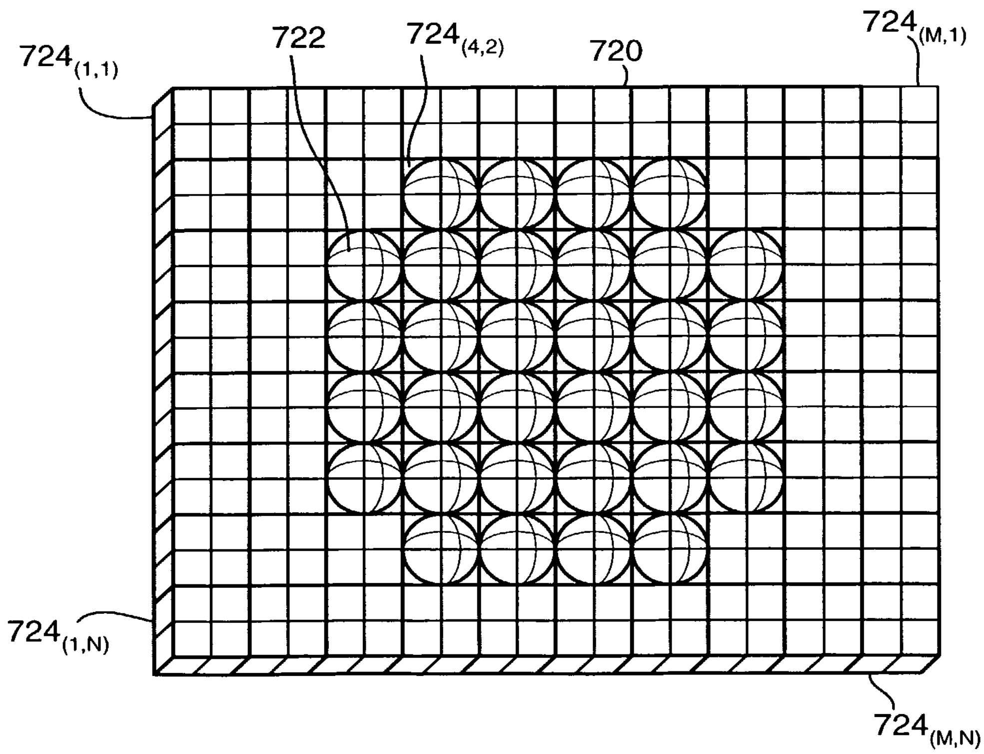

$724_{(1,1)}$
722
$724_{(4,2)}$
720
$724_{(M,1)}$
$724_{(1,N)}$
$724_{(M,N)}$

FIG. 17

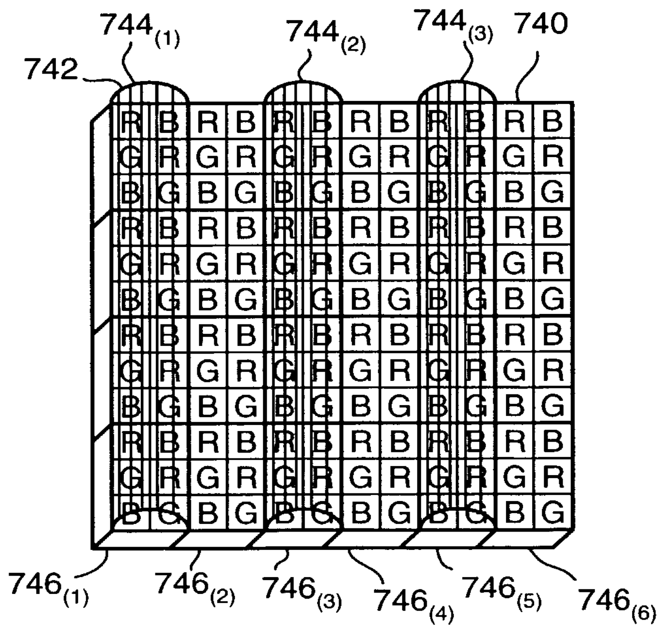

744(1)
744(2)
744(3)
740
742
746(1)
746(2)
746(3)
746(4)
746(5)
746(6)

FIG. 18

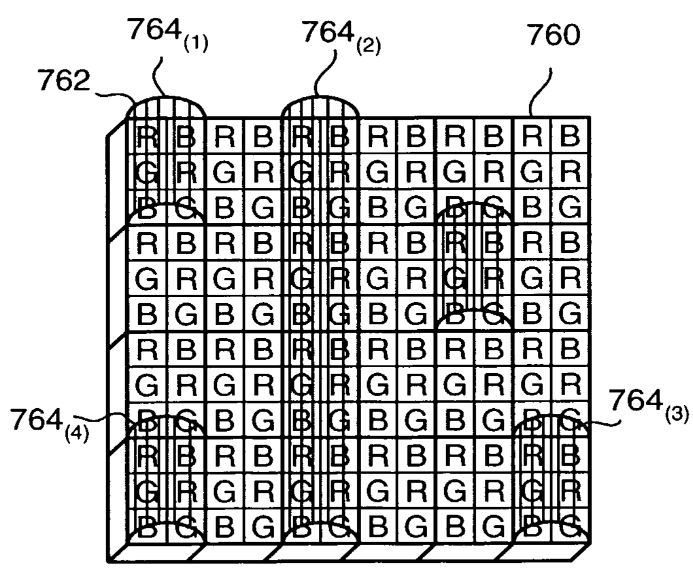

764(1)
764(2)
760
762
764(4)
764(3)

FIG. 19

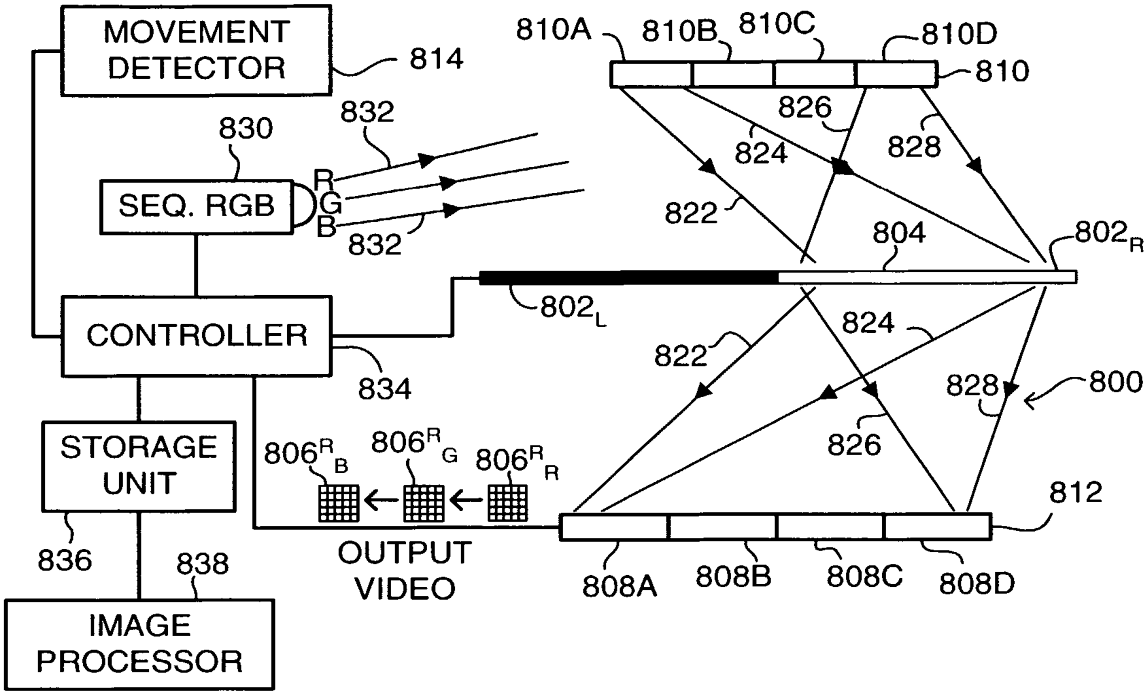


FIG. 20A

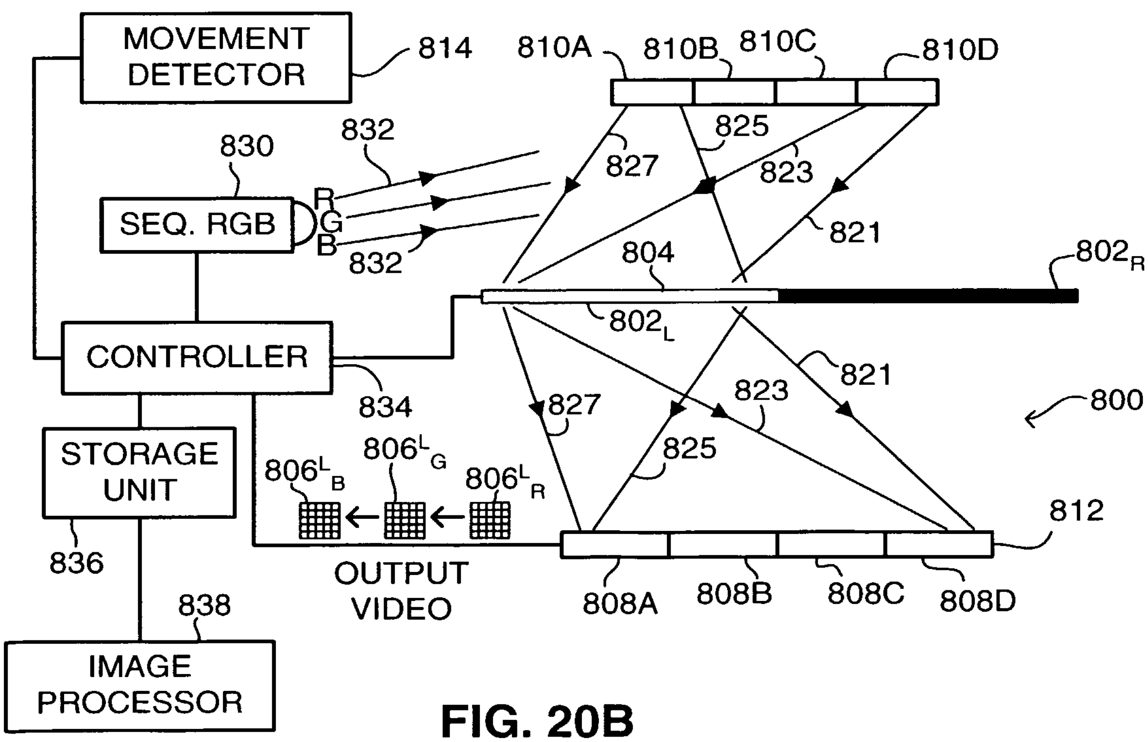


FIG. 20B

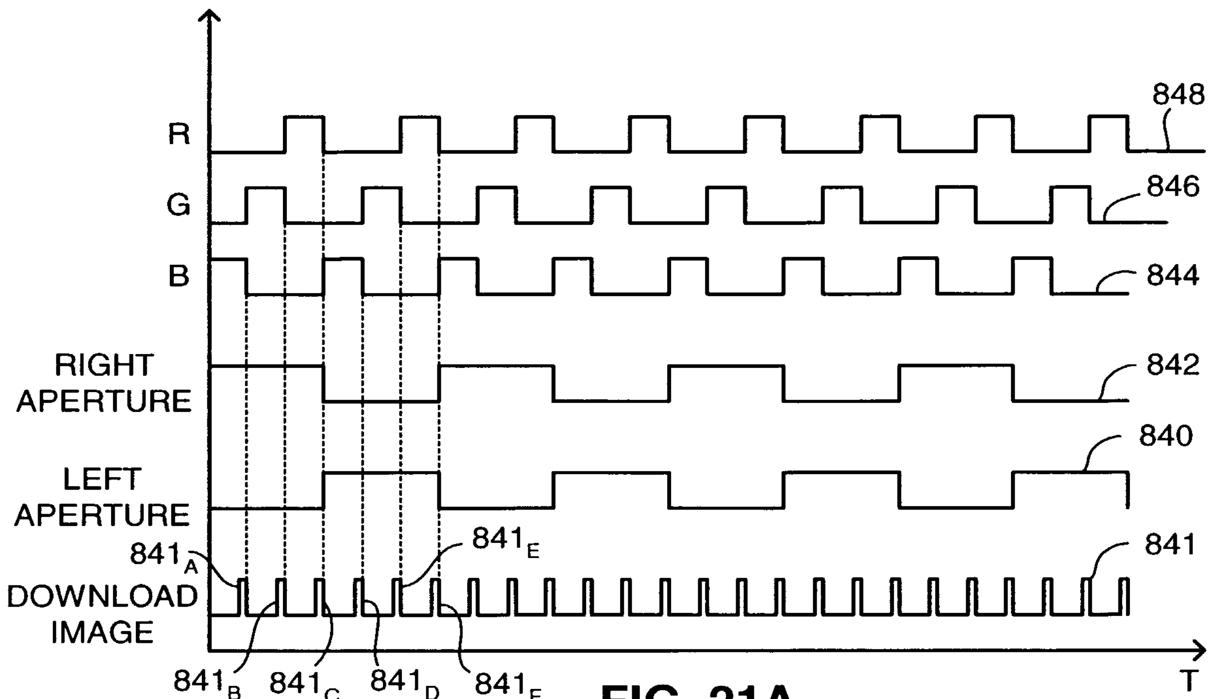


FIG. 21A

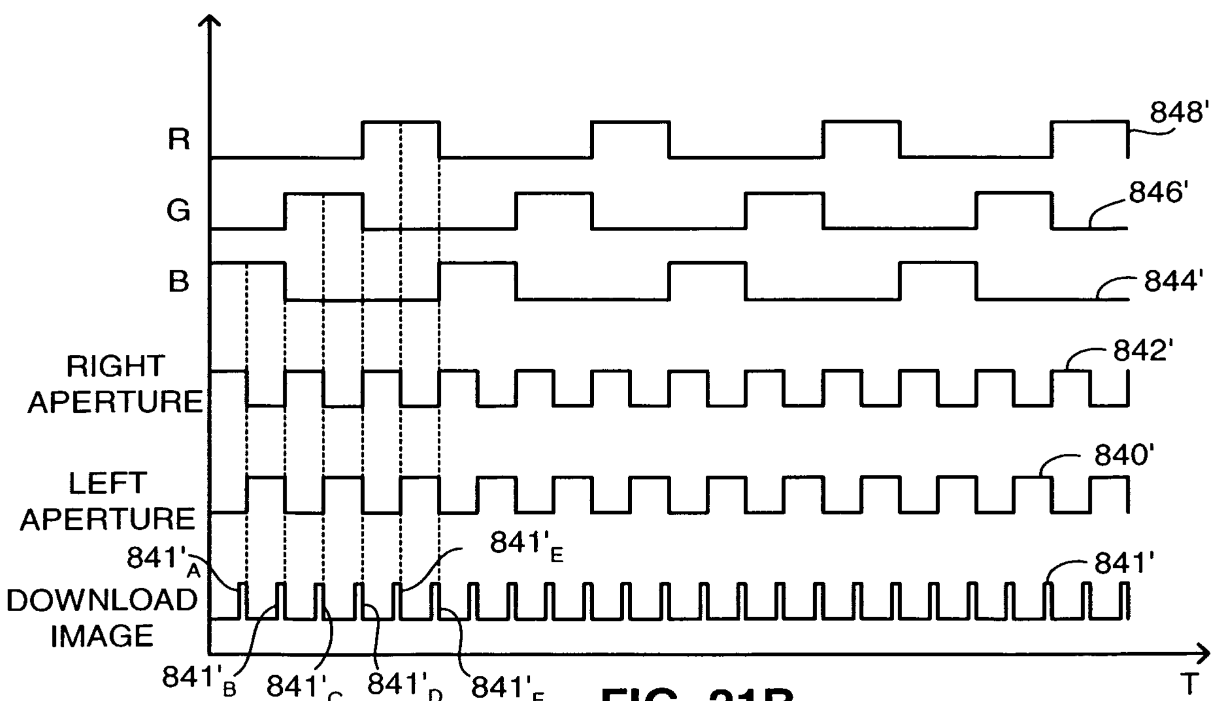


FIG. 21B

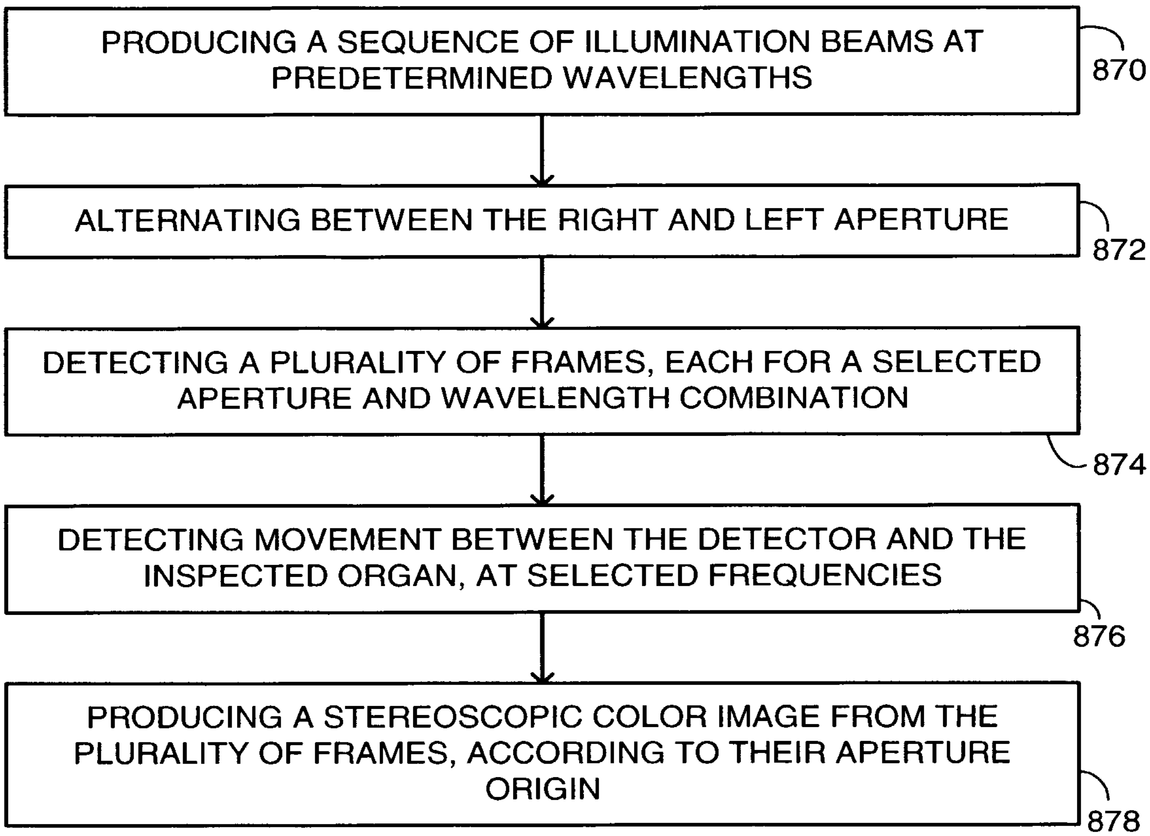

PRODUCING A SEQUENCE OF ILLUMINATION BEAMS AT PREDETERMINED WAVELENGTHS
870
ALTERNATING BETWEEN THE RIGHT AND LEFT APERTURE
872
DETECTING A PLURALITY OF FRAMES, EACH FOR A SELECTED APERTURE AND WAVELENGTH COMBINATION
874
DETECTING MOVEMENT BETWEEN THE DETECTOR AND THE INSPECTED ORGAN, AT SELECTED FREQUENCIES
876
PRODUCING A STEREOSCOPIC COLOR IMAGE FROM THE PLURALITY OF FRAMES, ACCORDING TO THEIR APERTURE ORIGIN
878

FIG. 22

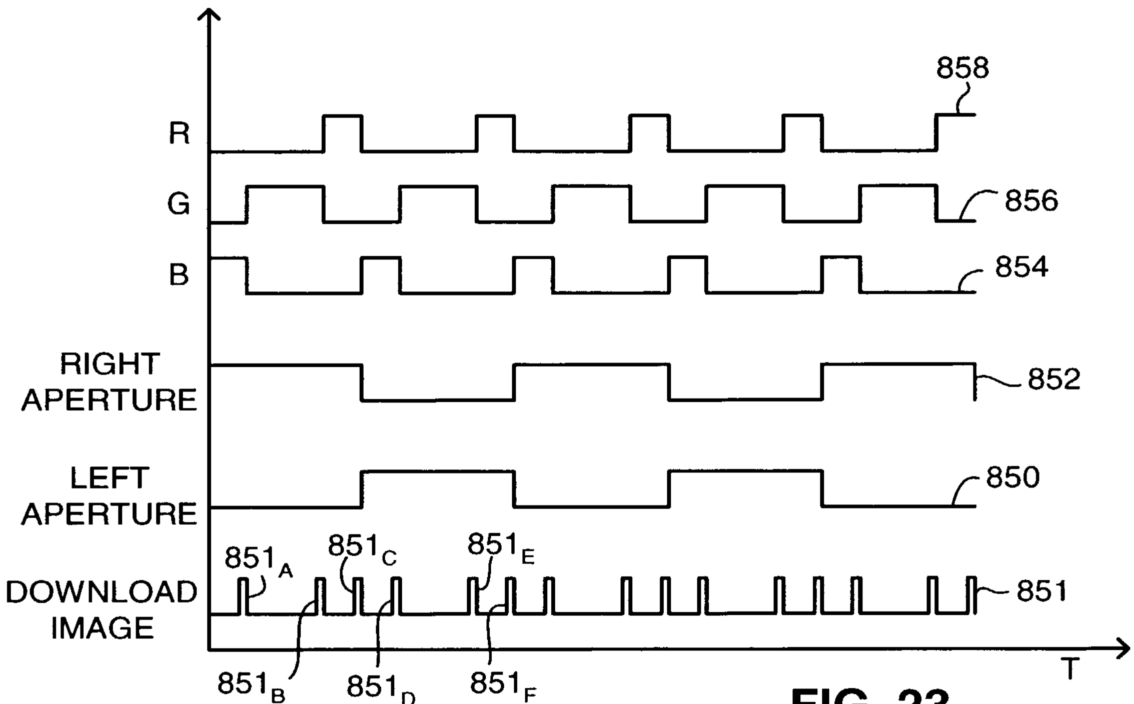

858
R
G
856
B
854
RIGHT APERTURE
852
LEFT APERTURE
850
851A
851C
851E
DOWNLOAD IMAGE
851
851B
851D
851F
T

FIG. 23

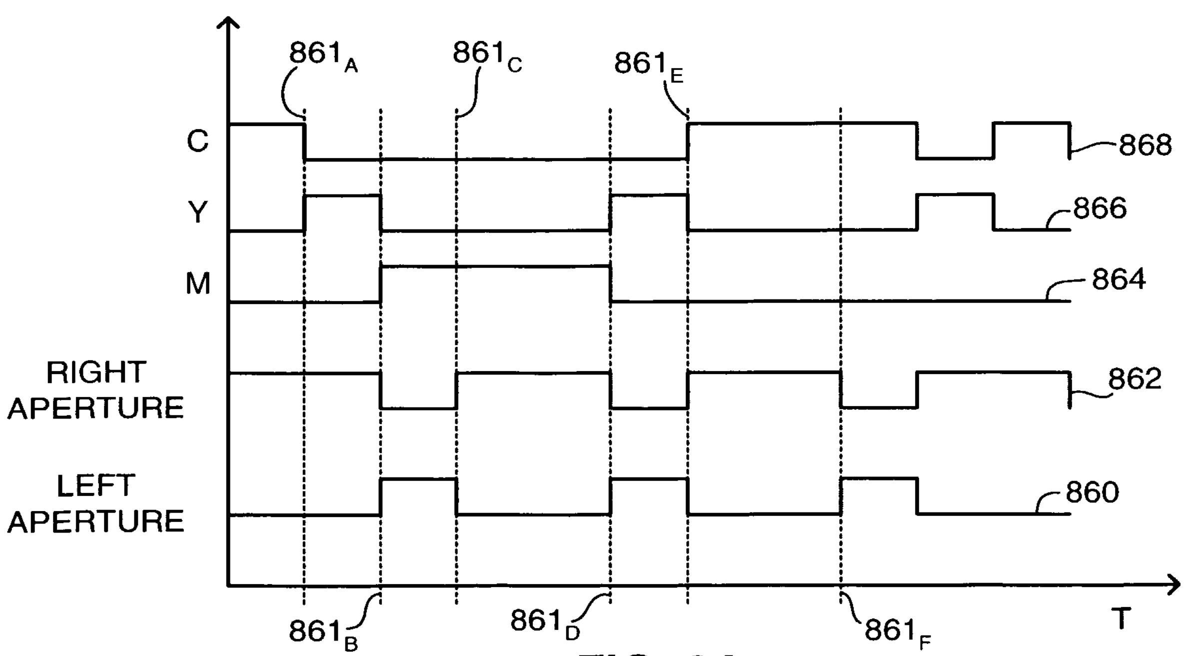

861A
861C
861E
C
868
Y
866
M
864
RIGHT APERTURE
862
LEFT APERTURE
860
861B
861D
861F
T

FIG. 24

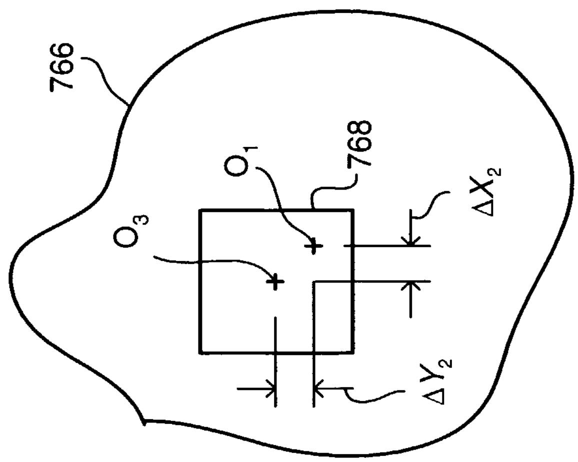


FIG. 25C

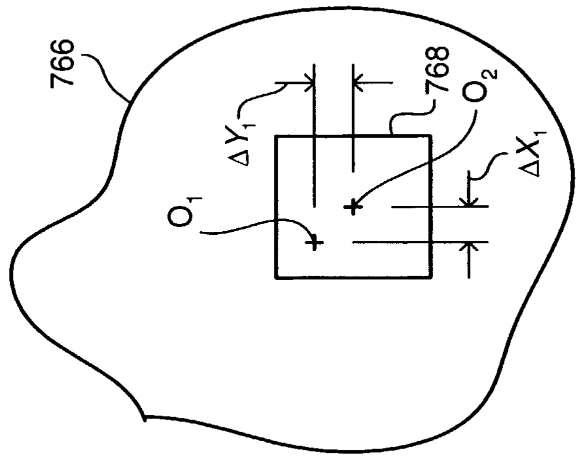


FIG. 25B

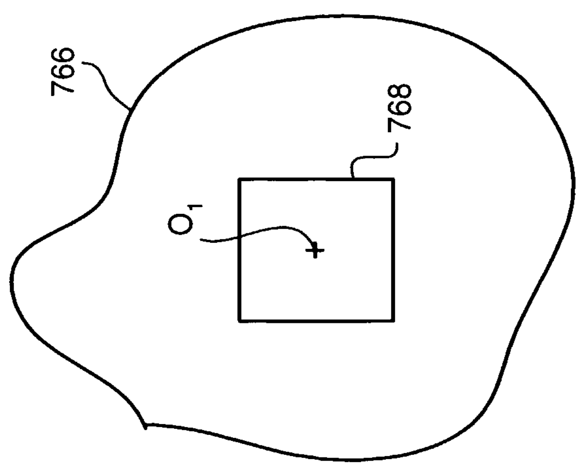


FIG. 25A

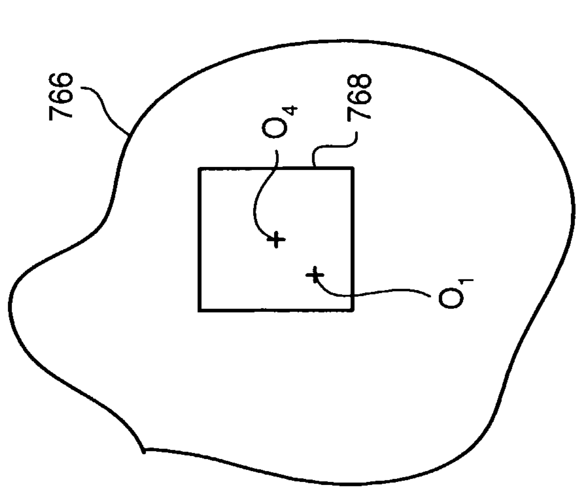


FIG. 25D

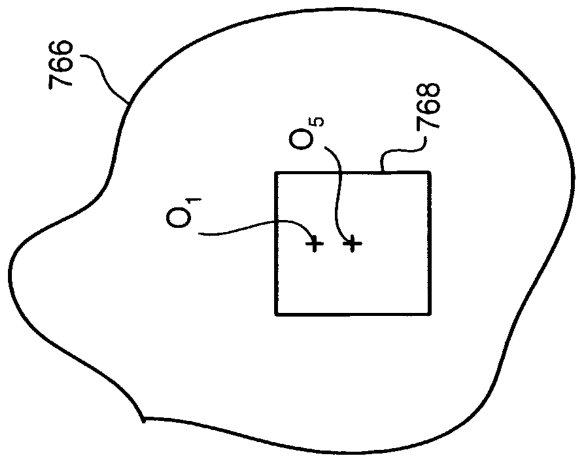


FIG. 25E

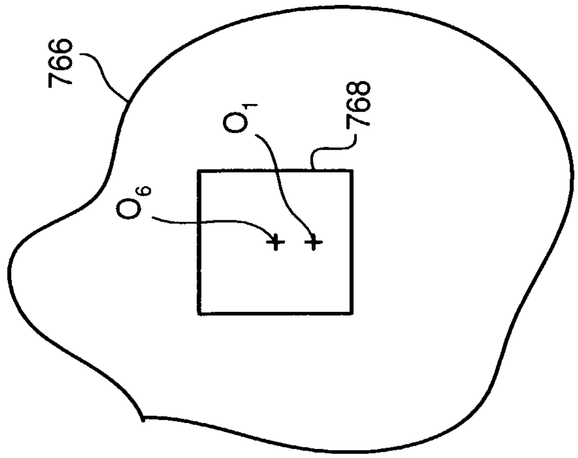


FIG. 25F

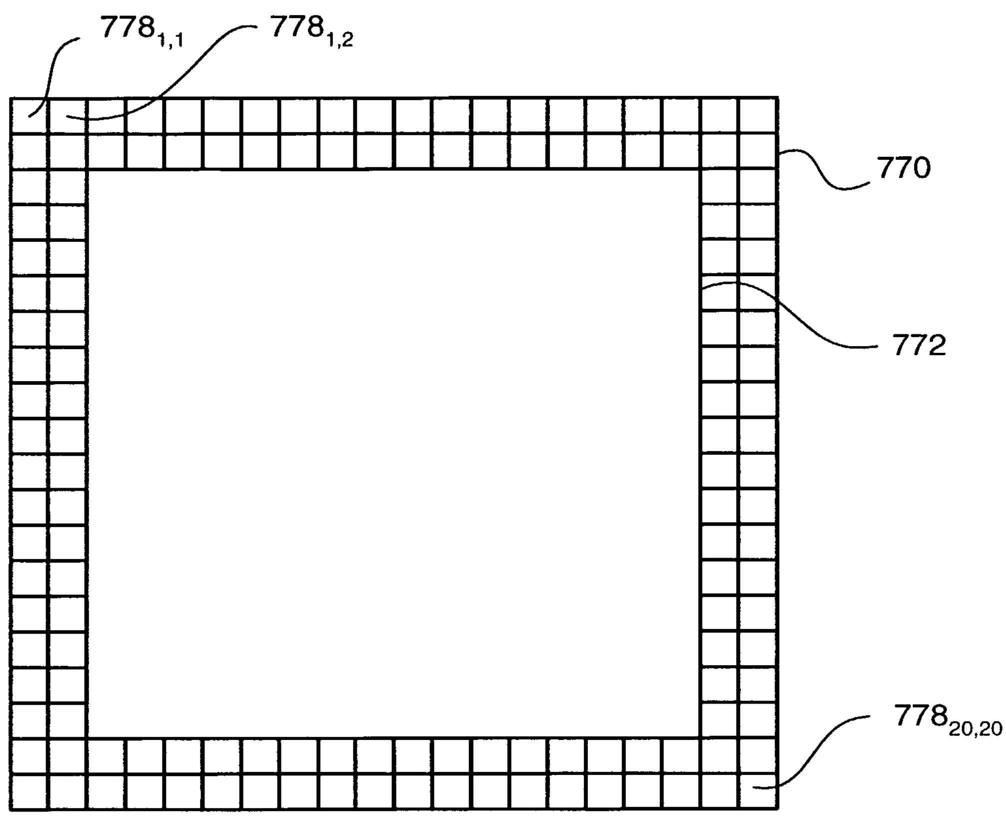


FIG. 26A

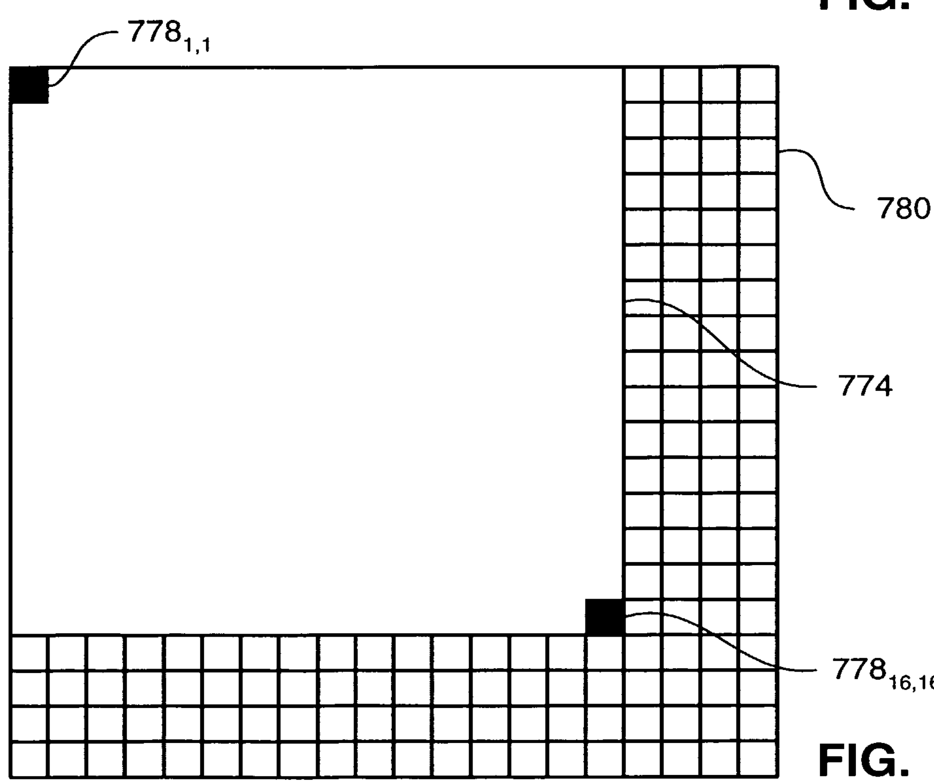


FIG. 26B

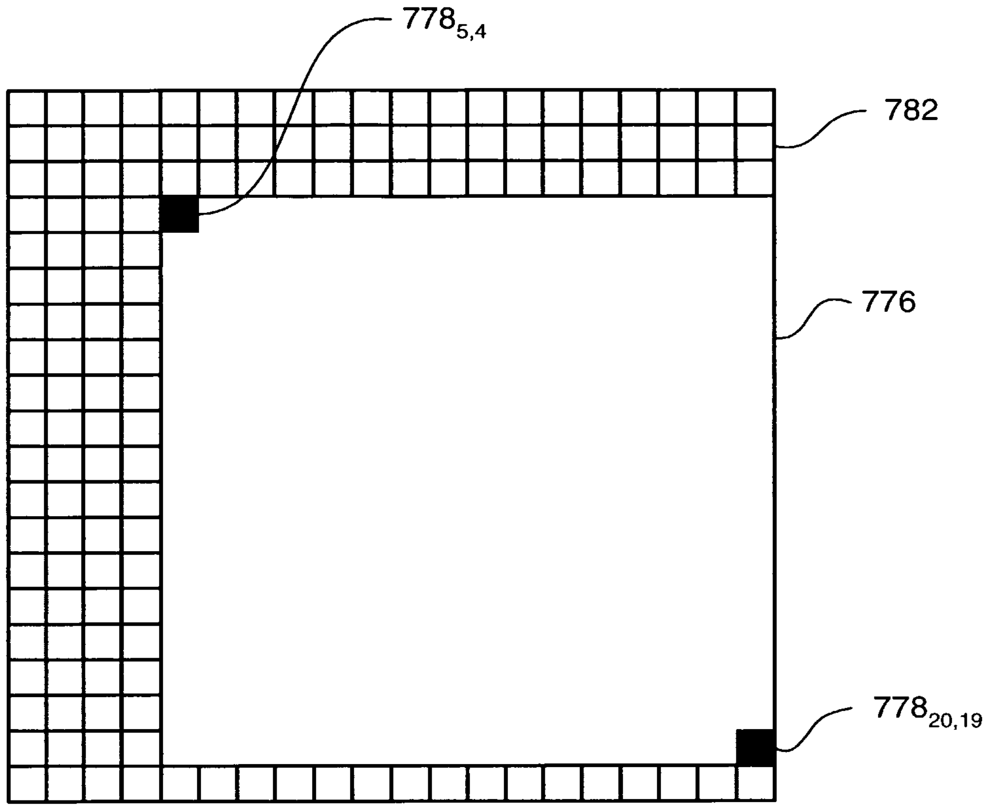


FIG. 26C

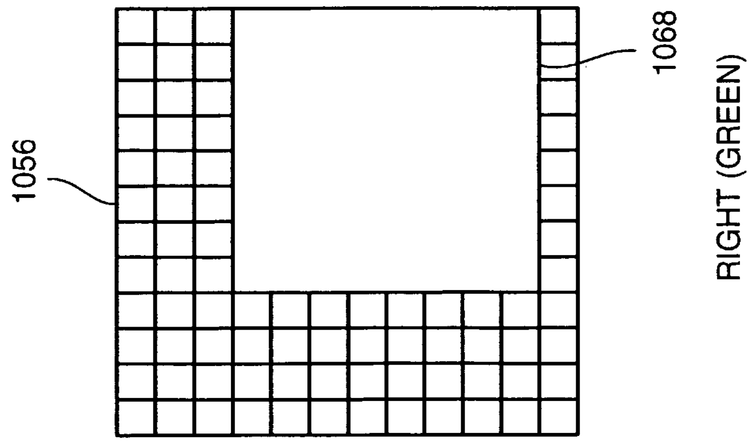


FIG. 27C

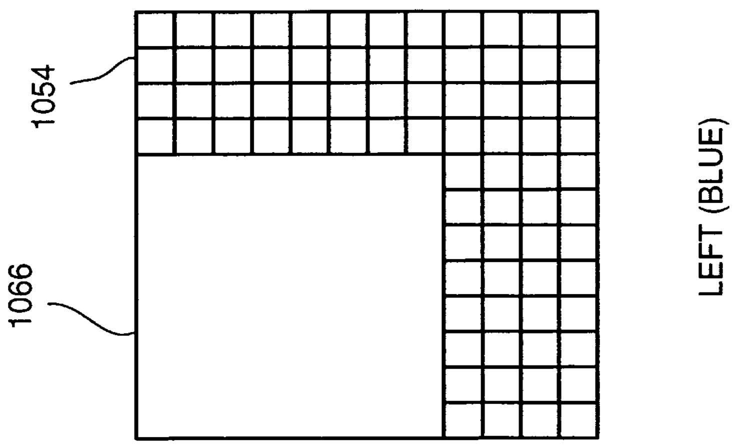


FIG. 27B

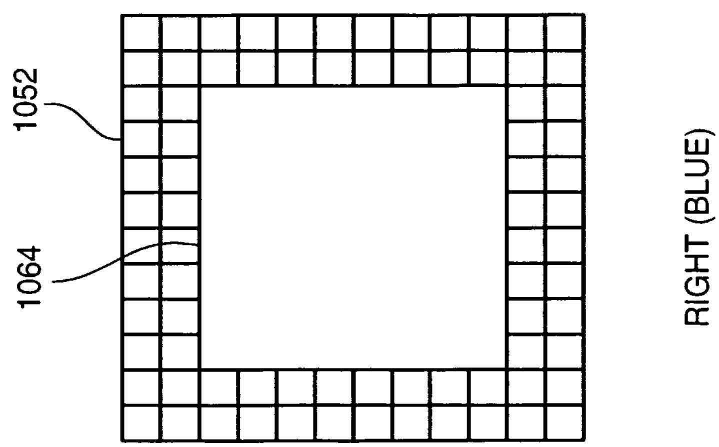
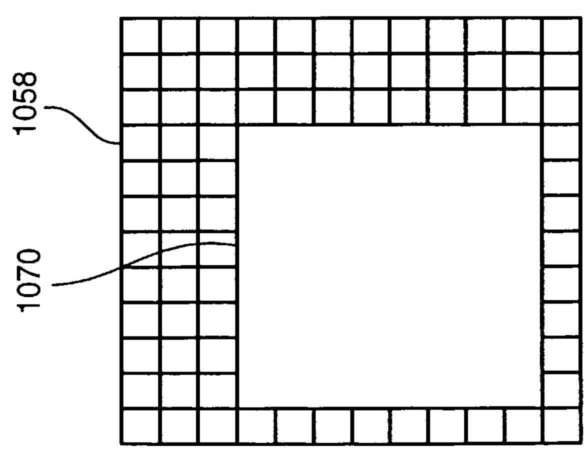
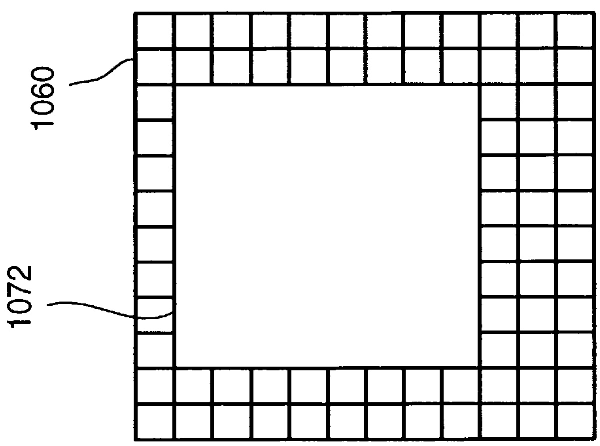


FIG. 27A



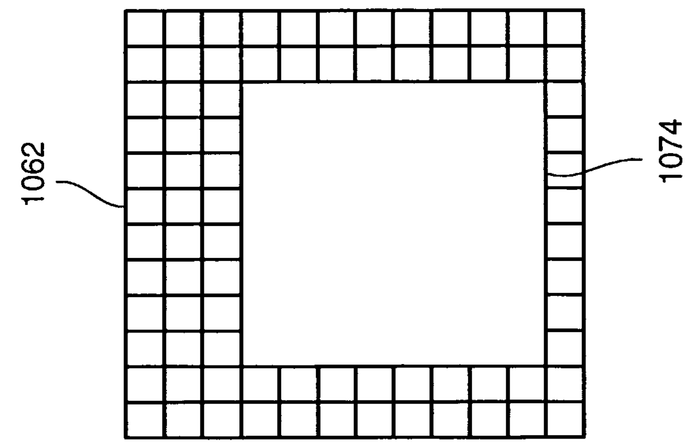
LEFT (GREEN)

FIG. 27D



RIGHT (RED)

FIG. 27E



LEFT (RED)

FIG. 27F

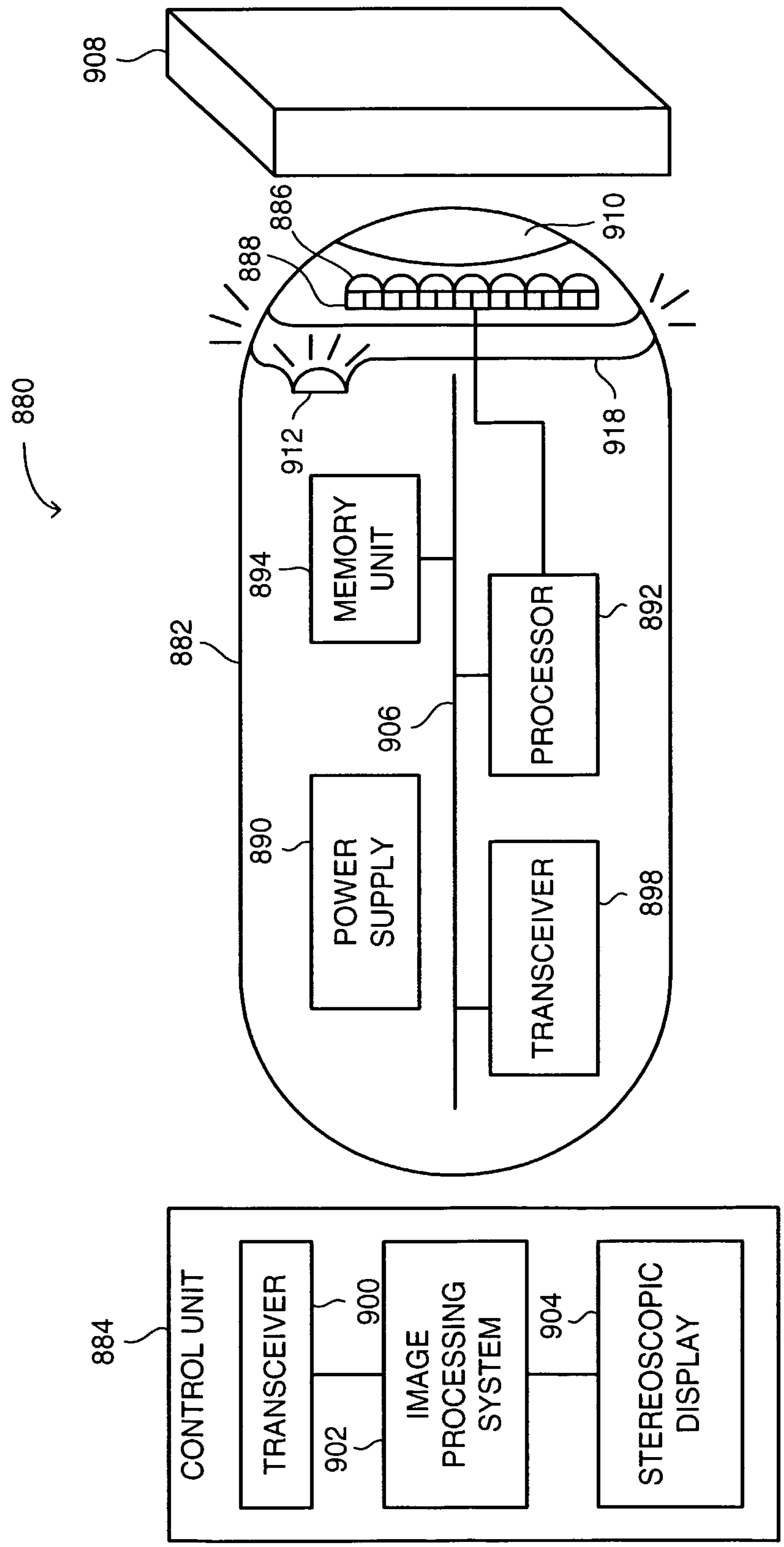

908
910
886
888
880
912
918
MEMORY UNIT
894
PROCESSOR
892
882
906
POWER SUPPLY
890
TRANSCEIVER
898
884
CONTROL UNIT
TRANSCEIVER
900
902
IMAGE PROCESSING SYSTEM
904
STEREOSCOPIC DISPLAY

FIG. 28

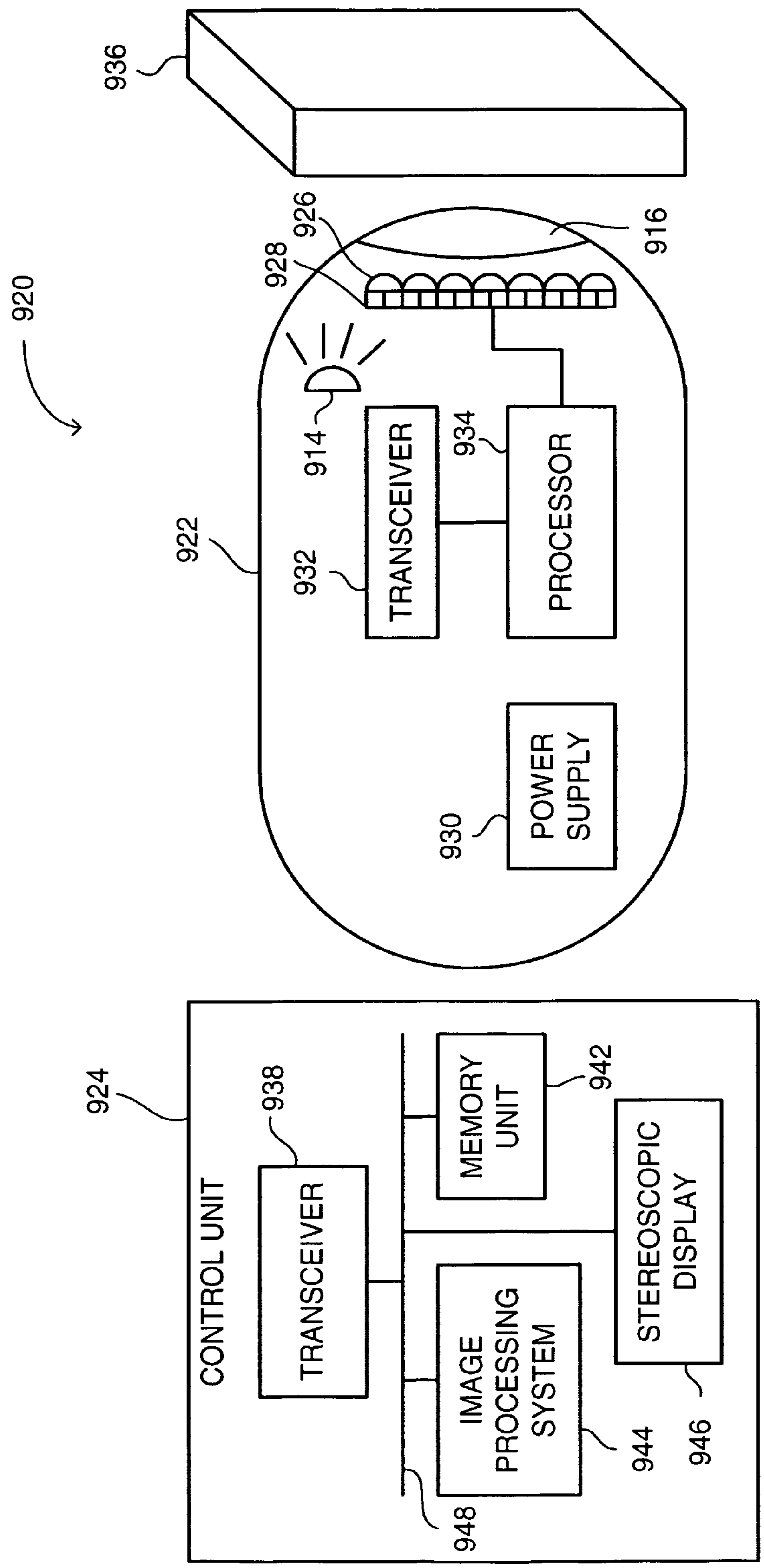

920
936
926
928
916
914
922
TRANSCEIVER
932
934
PROCESSOR
POWER SUPPLY
930
924
CONTROL UNIT
938
TRANSCEIVER
MEMORY UNIT
942
STEREOSCOPIC DISPLAY
IMAGE PROCESSING SYSTEM
944
946
948

FIG. 29

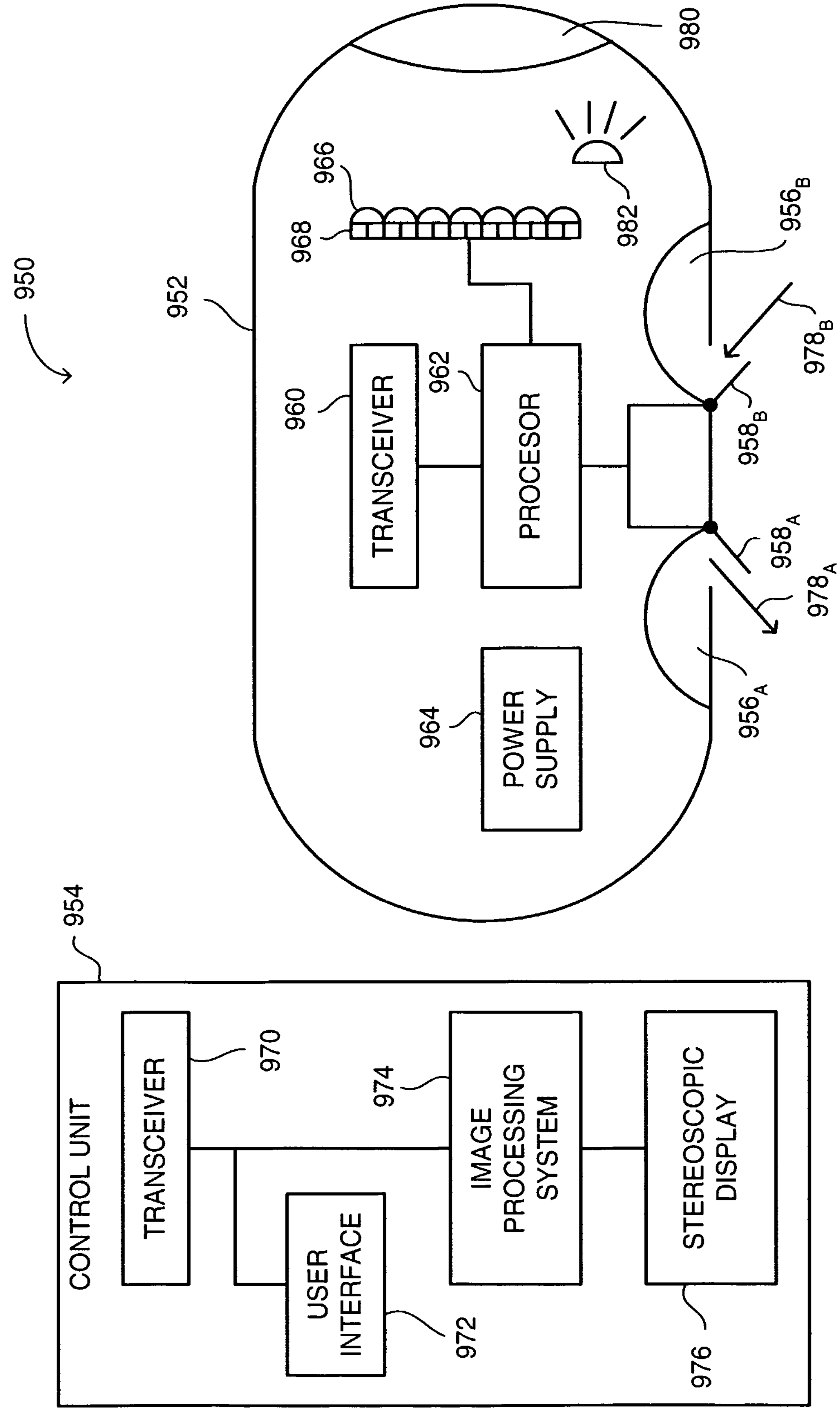

950
952
980
966
968
982
TRANSCEIVER
960
PROCESOR
962
POWER SUPPLY
964
956_B
978_B
958_B
958_A
978_A
956_A
954
CONTROL UNIT
TRANSCEIVER
970
USER INTERFACE
972
IMAGE PROCESSING SYSTEM
974
STEREOSCOPIC DISPLAY
976

FIG. 30

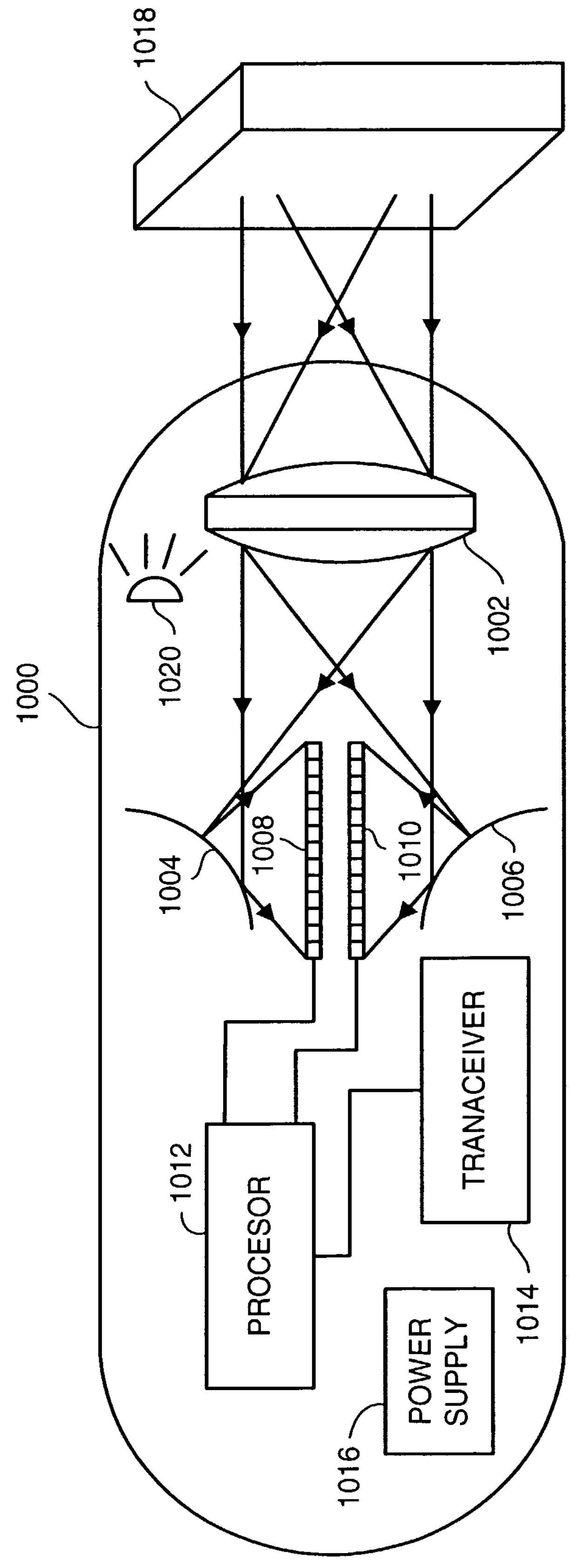
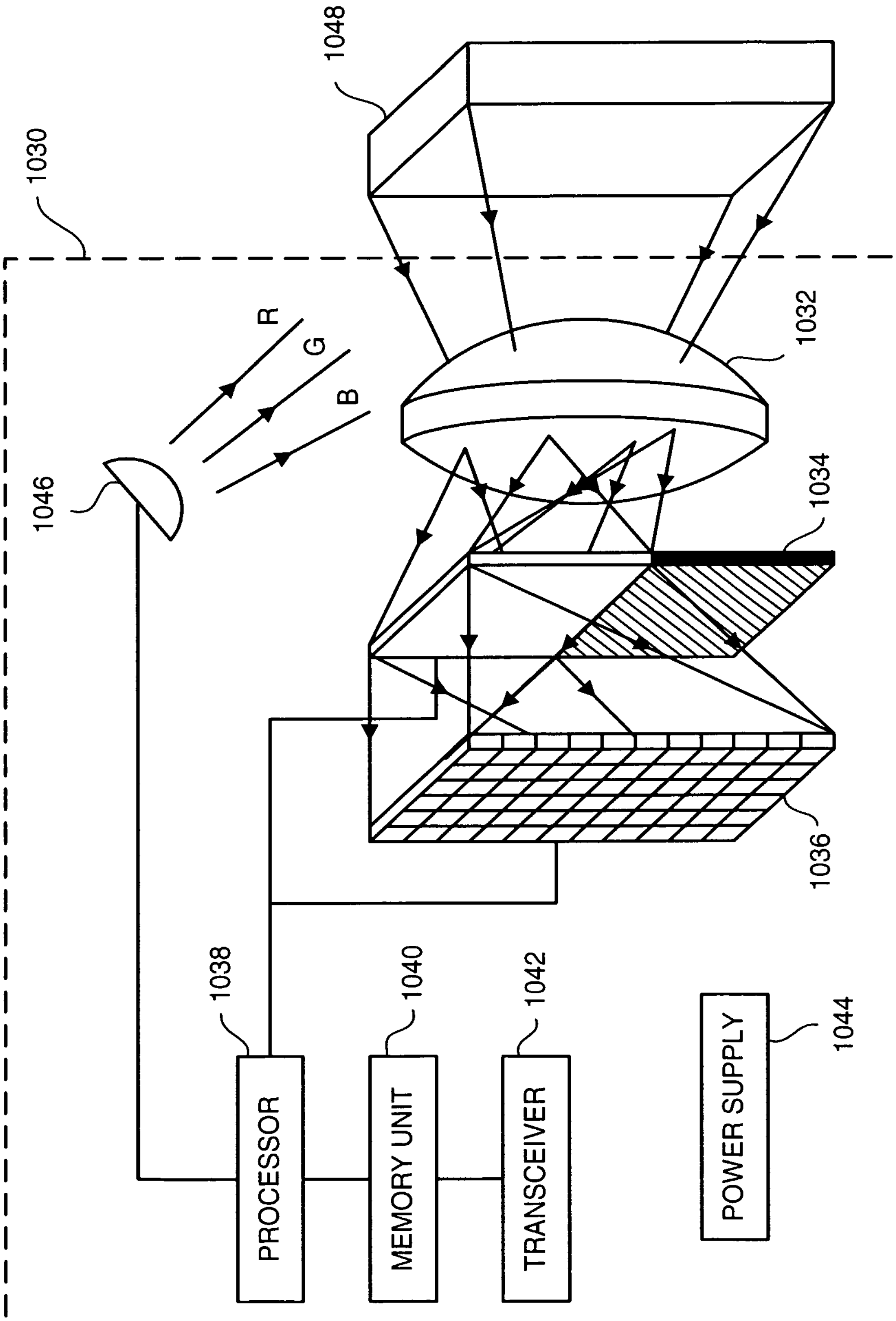

1018
1000
1020
1002
1004
1008
1010
1006
1012
PROCESOR
TRANACEIVER
1014
POWER SUPPLY
1016

FIG. 31


1030
1048
R
G
B
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1046
1034
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1038
1040
1042
1044
PROCESSOR
MEMORY UNIT
TRANSCEIVER
POWER SUPPLY

FIG. 32A

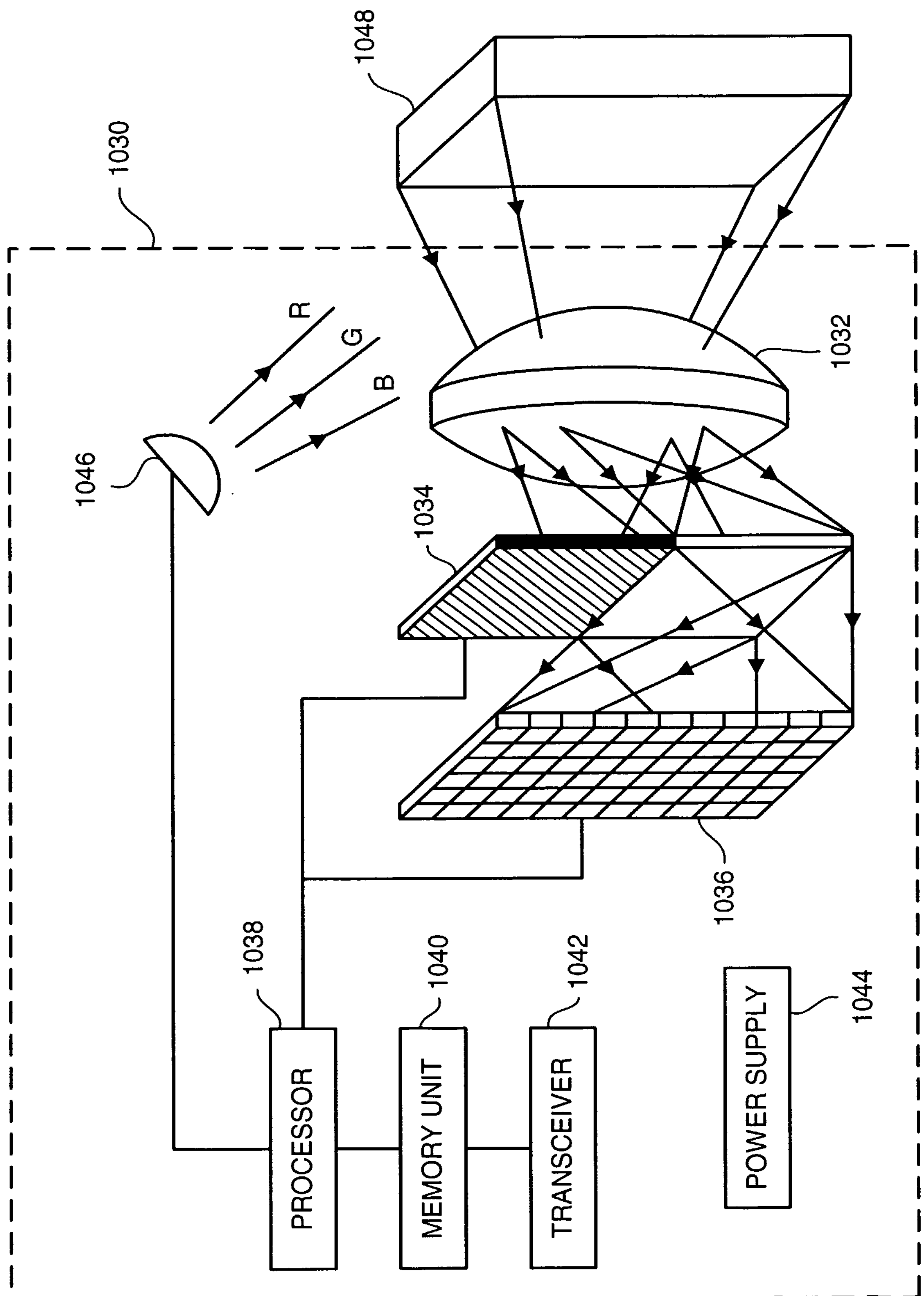
1030
1048
R
G
B
1046
1032
1034
1036
1038
1040
1042
1044
PROCESSOR
MEMORY UNIT
TRANSCEIVER
POWER SUPPLY

FIG. 32B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL02/00107

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :H04N 13/00
US CL :348/42, 51, 59
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 348/42, 51, 59, 751, 58; 356/4

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,966,168 A (MIYAZAKI) 12 October 1999, Figs. 9-10, col. 6, lines 23-52, and col. 7, lines 12-43.	1-25 and 73-74.
Y	US 5,076,687 A (ADELSON) 31 December 1991, Figs 1, 3A-3C, col. 2, lines 48-66, and col. 3, lines 1-23.	26-30, 36-44, 50-59, and 69-72.
Y	US 5,552,840 A (ISHII et al) 03 September 1996, Fig. 9, col. 6, lines 11-18.	31-33, 45-47, and 60-64.
Y	US 5,034,805 A (ISHIZAKA) 23 July 1991, Fig. 1.	34-35, 48-49, and 65-68.

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search	Date of mailing of the international search report
05 JUNE 2002	12 JUL 2002
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer SHAWN AN Telephone No. (703) 305-0099

Form PCT/ISA/210 (second sheet) (July 1998)★